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EROSION OF THE NORTH SHORE OF LONG ISLAND

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PREPARED WITH
SUPPORT
FROM THE
NASSAU - SUFFOLK
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ABSTRACT

The instability of beaches and bluffs of the north shores of Nassau and Suffolk Counties is described over geologic time and as influenced by individual storms.

The geologic history and present features of the shoreline are described. An inventory is provided of shoreline length, bluffs, dunes, sediment characteristics, summer beach profiles, shore zone vegetation, and man-made structures designed to modify natural processes. The influences of natural processes which continually modify these shoreline features are also described. These processes are sea level changes, winds, waves, tides, littoral transport, and rain runoff. Emphasis is placed upon the major short-term influences of storms, including their frequencies and intensities.

The extremely expensive attempts of man to inhibit dynamic beach processes are evaluated. Results of these attempts are often found to be unpredictable and either ineffective or detrimental.

Large areas of the shore zone are found to be subject to infrequent tidal flooding. These areas are mapped and the numbers of structures located in this flood plain are enumerated.

A detailed case history is presented of the geological processes influencing the Crane Neck region north of Stony Brook Village.

The features of beaches and the historical rates of erosion or accretion at 158 locations are summarized in a Beach Utility Index designed to guide the most rational use of specific shoreline reaches. In addition to estimates of erosion and accretion rates, this utility index summarizes at specific locations the natural barriers to erosion, beach width, sediment grain size of the forebeach and backbeach, and accessibility to the beach.

A number of recommendations are made to reduce the likelihood of fatalities and property damage in the shore zone by restricting development in hazardous areas. The recommendation is also made that future engineering structures designed to stabilize portions of the beach should not be constructed without detailed knowledge of their influences upon adjacent property.

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Chapter 1

INTRODUCTION

The Erosion Problem of Long Island's North Shore: the Objectives and Scope of this Study

Beach and bluff erosion on Long Island's north shore has produced important social, legal and political issues. The issues are too often based on the expectation that the shoreline will remain stable after residential, recreational or commercial development. Developers soon realize that the shoreline is not static; it is subject to both short- and long-term processes which change its configuration. Beaches can either erode or accrete naturally, depending on their position in relation to the sources of sand supply, their exposure to wind waves, and the direction and intensity of littoral transport, i.e. "the movement of material along the shore in the littoral zone by waves and currents" (U.S. Army Coastal Engineering Research Center, 1966, p. A-20).

Unlike the dunes on the barrier bars and spits so typical of Long Island's south shore, which can either erode or accrete depending on storm and wind conditions, the bluffs of Long Island's north shore can only remain stable or recede. Stable bluffs are usually associated with gradually sloping bluff faces, vegetative cover and wide protective beaches; whereas receding bluffs are usually those with steep bluff faces, little or no vegetative cover and narrow beaches. Bluff recession results from the erosive effects of storm tides, spring discharge and rain runoff.

Coastal erosion on Long Island's north shore has been designated "critical" by the U.S. Army Corps of Engineers (1971a). According to this report, the rate of erosion and character of development in such critical areas justify the use of beach nourishment (replenishing a beach through deposition of dredged materials) or the construction of shore protection devices to alleviate the erosion problem. The estimated first cost for shore protection in the form of beach nourishment along the entire north shore of Nassau and Suffolk Counties is more than 100 million dollars (U.S. Army Corps of Engineers, 1971a, p. 104). This estimate does not include the price of annual beach nourishment for maintenance purposes.

Improved transportation facilities and a better standard of living and more leisure time have caused extensive development of Long Island's shores during the last 30 years for both residential and recreational purposes (Renshaw, 1969). Swimming is by far the most popular outdoor recreational activity for residents of the bi-county region and also for the many summer visitors who frequent the shores of eastern Long Island (New York State Office of Planning Coordination, 1971). Early development of the shoreline often proceeded without due regard for shoreline erosion trends. Storm wave attack and shore recession structural damage, loss of shorefront property and loss of business have resulted in the construction of shore-protection devices and beach fill along the north shore. The data of Table 1-1 show the number and type of such structures as of 1965 along the north shore of Suffolk County. Shore protection investment in terms of 1971 prices is also shown.

Many groups and communities have requested federal aid for additional structures (U.S. Army Corps of Engineers, 1969). Federal financial assistance for shore-protection projects on public land cannot exceed 70 percent of the construction cost, with the remaining 30 percent assumed by local and state government. However, if the shore in question is privately owned, and there is no public use of the land or benefit in its protection, then federal funds cannot be authorized for the project (U.S. Army Corps of Engineers, 1970). Therefore, little federal aid is available for the north shore of Suffolk County, because

81 percent of the 139 km (86 mile) shoreline is privately owned (U.S. Army Corps of Engineers, 1971a).

Table 1-1. SHORE PROTECTION STRUCTURES AS OF 1965, NORTH SHORE, SUFFOLK COUNTY, NEW YORK[a]

Structure	Number	Length (m)	Cost/m[b] (dollars)	Range of Existing Investment (millions of dollars)
Groins	237	7073	656 to 2,296[c]	4.6 to 16.2
Jetties	14	2768	656 to 2,296[d]	1.8 to 6.4
Bulkheads	101	8651	245 to 327	2.1 to 4.2
Seawalls	34	5235	656 to 1,635	3.4 to 8.6
Revetments	2	534	245 to 490	0.1 to 0.3
Total Investment				12.0 to 35.7

[a]U.S. Army Corps of Engineers (1969).
[b]U.S. Army Corps of Engineers (1971). Shore protection guidelines. Washington, D.C., 59 p.
[c]Mr. James Daniels, Beach Erosion and Hurricane Section, New York District, U.S. Army Corps of Engineers, supplied the groin cost figures. The lower limit represents the cost of timber groins, while the upper limit represents the cost of stone groins similar to those constructed on the south shore barrier beaches.
[d]Jetty costs per meter are assumed to be the same as the cost for groins.

Shore-protection structures change the dynamics of beach equilibrium and can result in unwanted accretion or erosion. In Suffolk County, severe beach and bluff erosion has been reported by residents of Jamesport and Wading River who allege that jetties constructed by the Curtiss-Wright Corporation and LILCO, respectively, have blocked the supply of sand that nourished their beaches (Newsday, 2/9/71, p. 10; 3/11/71, p. 21; 6/21/71, p. 3; 7/12/71, p. 6; 9/27/71, p. 7; 4/13/72, p. 16).

Shoreline development in the bi-county region will increase in the future (Nassau-Suffolk Regional Planning Board, 1970). Most of this growth will occur along the shores of Suffolk County, because the shores of Nassau County have already experienced extensive development. The Nassau-Suffolk Regional Planning Board estimates that the bi-county population will increase by 800,000 in the period 1970 to 1985, requiring roughly 24,000 acres of additional recreational and open space land by 1985 for local residents alone (New York State Office of Planning Coordination, 1971). The immense popularity of swimming as a recreational activity may necessitate the development of extensive tracts of land at the shore. The north shore of Long Island, especially that portion located in Suffolk County which is used relatively little, has tremendous potential in helping to solve the region's shoreline recreational needs. Suffolk County has already included parts of the north shore in its capital acquisitions program for preservation purposes (Klein, 1972).

Development of the north shore will require long-range planning based on increasingly thorough understanding of the processes affecting the configuration of the shoreline. Knowledge of beach and bluff erosion trends can be used to great economic advantage for land acquisition and development. Areas with histories of accretion should receive more favorable consideration in planning future development than areas with histories of erosion. Perhaps acquisition costs can be decreased if the value of a piece of shorefront land is decided on the basis of its "expected life" as a piece of property. Increased knowledge of littoral forces can be used to minimize the likelihood of deleterious effects of shore protection structures.

Chapter 2 discusses the causes and effects of the erosion problem on Long Island's north shore. The problem consists of the effects of tidal flooding and shoreline change on beaches and shoreline development. Information is presented from a geologic point of view which assumes that the present beach and shoreline are the result of natural forces acting over long periods of time (Krumbein, 1963). The main objectives of Chapter 2 are:

1. to present a brief physical description of Long Island's north shore;
2. to assess winds, waves and tides as littoral forces affecting the north shore;
3. to assess hurricanes and extratropical storms as active geologic agents, and describe the effects they have on different shore environments.

These objectives form part of the suggested general approach to be used in solving the erosion problem on Long Island's north shore as mentioned in Section 1.5 of Bartholomew and McGuinness (1972).

Chapter 3 presents an inventory of the north shore in terms of shoreline erosion and accretion, bluff recession and flood plain delineation. Grain size analyses and beach width measurements are shown for selected locations. A Beach Utility Index is developed from shore history and characteristics. The Utility Index can be used to visualize beach qualities quickly, and as a tool for planning future beach use.

Chapter 4 is a case study of one section of the north shore, Crane Neck, over an 80-year period. The Beach Utility Index developed in the previous chapter is applied here, and specific recommendations are made for future management and beach development.

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Chapter 2

STABILITY OF THE NORTH SHORE, LONG ISLAND, NEW YORK

Literature Review

A comprehensive study of shore processes and beach dynamics has not been made for Long Island's north shore. Early investigators such as Mather (1843) and Johnson (1925) described the region's geomorphology. North shore erosion was recognized as an economic problem by the New York State Legislature in 1947. The U.S. Army Corps of Engineers (1969) published a beach erosion control and interim hurricane study covering the north shore of Suffolk County. A comparison report is, however, sorely needed for the north shore of Nassau County. The U.S. Army Corps of Engineers (1971a) also includes Long Island's north shore as part of its national shoreline inventory.

The north shore of Long Island is classified as a glacial deposition coast by Shepard (1963). Initial irregularities of the submerged moraine coast have been smoothed out by marine erosion and deposition with the result that the coast is in a submature stage of development (Johnson, 1919; 1925). The beach environment of the north shore is similar in many respects to other areas in the Long Island Sound-New England region (U.S. Geological Survey, 1970, p. 79).

Physical Characteristics of the North Shore

A. Physiography of the Long Island North Shore Region

The main topographic features of the Long Island north shore region are the Long Island Sound valley, the north shore harbors and bays, and the north shore scarp and plateau.

The depression that is now Long Island Sound had its origin during Tertiary time when sea level was lower than it is at present (Suter, deLaguna and Perlmutter, 1949). A stream (Sound River) developed along the interface of the Cretaceous sediments of the south with deeply weathered bedrock to the north. This occurred some distance south of the present Connecticut coast (Johnson, 1925). The Cretaceous sediments formed a ridge with a gentle southern slope and a steep northern slope, cut by the transverse valleys of north-flowing streams. These streams joined the Sound River at the base of the ridge. Veatch (1906) believed that the Sound River, which occupied a drainage basin aligned in a north to south fashion similar to that of the Connecticut River, flowed in a westerly direction before cutting across the area that is presently Queens and Jamaica Bay to enter the Hudson Canyon on the continental shelf. Fuller (1914) thought that the westerly flow of the Sound River was obstructed by the deposition of the Gardiners and Manhasset formations, with the result that flow was diverted to the east. Suter et al. (1949) discounted the evidence for a westward-flowing Sound River, and stated that it flowed to the east in a channel at the base of the ridge. This channel presumably turned south in the Peconic-Shinnecock Bay area of Long Island and eventually reached the Hudson Canyon.

Evidence suggests that the Long Island Sound depression was the site of a large periglacial lake or several smaller ones, formed after the glacial ice which deposited the Harbor Hill terminal moraine about 17,000 years ago receded north into New England (Sirkin, 1967). The lake or lakes were drained prior to the rise in sea level which inundated the Sound basin (Grim, Drake and Heirtzler, 1970).

The north shore harbors and bays apparently are in locations coincident with the valleys of the Cretaceous erosion surface formed during the Tertiary (Fuller, 1914). The Cretaceous rocks were covered by the Manhasset formation and, later on, by Wisconsin drift and till. The Manhasset formation is a plateau 30 to 60 m (100 to 200 ft) above sea level, sloping gently toward the south. A scarp, originally the ice contact slope of the Manhasset glacier and later subdued by Wisconsin ice erosion, faces this plateau. Since stabilization of sea level, marine forces have cut bluffs and a narrow bench in the scarp and worn away its projecting headlands.

The headlands of the north-draining valleys to the east of Port Jefferson have been eroded by wave and current action. For the most part, the remnant headlands, such as Herod, Roanoke, and Horton Points, are the result of geologic control, as the clay and till layers which outcrop in the bluffs at these areas are more resistant to erosion than the layers in nearby regions (U.S. Army Corps of Engineers, 1969). Because of the southeast slope of the bedrock beneath Long Island, a smaller volume of Manhasset material lies at or near sea level in the eastern section of the north shore than in the western section. Therefore, the north shore plateau is inconspicuous or invisible in this eastern region.

The north shore of Long Island can be divided into two segments on the basis of topography and shoreline trends. The eastern segment from Port Jefferson Harbor to Orient Point is approximately 110 km (68 miles) long; the western section from Port Jefferson to Willets Point on Little Neck Bay is approximately 240 km (149 miles). These distances include the shoreline of bays and harbors.

B. Shoreline West of Port Jefferson

The shoreline west of Port Jefferson is highly irregular, indented by several deep harbors and bays: Little Neck Bay, Manhasset Bay, Hempstead Harbor, Oyster Bay, Cold Spring Harbor, Huntington Bay, Stony Brook Harbor and Port Jefferson Harbor. These bays and harbors occupy positions which were formerly the valleys of the north-draining streams of Cretaceous time (Fuller, 1914). They are separated by peninsulas or necks which project into Long Island Sound. The narrow beaches of the necks are backed in some areas by the fresh cliffs or bluffs of the shore scarp. The bluffs are mainly composed of the Manhasset formation, a combination of till and outwash deposits which is covered by a thin layer of Harbor Hill till and retreatal outwash. Bluff height is generally low (roughly 10 m) in the extreme western portion of the island near Manhasset and Little Neck Bays, and increases to between 23 m (75 ft) and 33 m (110 ft) at Lloyd Point, Eatons Necks and the Nissequogue area. Further east the bluffs are less elevated - about 26 m (85 ft) at Crane Neck Point and 12 m (39 ft) at Old Field Point, with small pocket beaches located between the projecting points of the necks.

Elevations increase abruptly from 60 m (200 ft) to 90 m (295 ft) in the centers of the necks and in the regions at the heads of the harbors. The Harbor Hill terminal moraine is located south of the harbors and intersects the coast east of Port Jefferson, near the vicinity of Rocky Point (Flint, 1971, p. 581). Material eroded from the necks and offshore islands* was deposited as spits (e.g. West Beach on Eatons Neck), baymouth bars (e.g. Old Field Beach at Port Jefferson Harbor) and tombolos (bars like Asharoken Beach which connect offshore islands to the mainland). Dune sands are frequently associated with these depositional forms. Marshes, such as those at Stony Brook Harbor, Flax Pond and West Meadow Beach, generally occupy small depressions in the coast and are separated from the Sound by beach deposits.

C. Shoreline East of Port Jefferson

The shoreline east of Port Jefferson comprises gently curved beaches separated by headland areas which project only a slight distance seaward of the

*Areas such as Eatons Neck were once offshore islands.

general shore trend. For the most part, the headlands are associated with high bluffs, such as the 42 m (140 ft) elevation at Herod Point. East of Port Jefferson, the Harbor Hill terminal moraine crowns the north-shore scarp. This moraine contains more boulders (glacial erratics) than its southern counterpart, the Ronkonkoma moraine (Muller, 1965). Boulder lag deposits are often found in the projecting headlands of the north shore.

East of Port Jefferson the bluffs are more continuous than those to the west. In general, bluff height decreases from Port Jefferson to Orient Point. Between Port Jefferson and Herod Point, the bluff height ranges from 30 m (100 ft) to 42 m (140 ft). East of Herod Point, bluff height gradually decreases, reaching approximately 10 m (33 ft) near Orient Point. Marshes and beach deposits, such as those found at Mt. Sinai Harbor, Wading River and Fresh Pond, have accumulated in depressions where the bluff is discontinuous. Other sections, for example Friars Head, are composed of wind-blown deposits in the form of dunes. In some sections, such as near Sound Beach, wind deflation (the removal of material by wind action) of bare bluff faces has formed dunes on the tops of the bluffs. Low bluffs and scattered hills are found immediately west of Orient Point.

Shoreline Features and Processes

A. Beaches, Beach Processes and Nomenclature

Perhaps the most useful definition of a beach is "the zone of unconsolidated material extending landward from the mean low water line to the place where there is a change in material or physiographic form, as for example, the zone of permanent vegetation, or a zone of dunes or a sea cliff" (Kukal, 1971, p. 209). Beaches are among the most variable of landforms in that they can erode, accrete or remain stable over time. Long-term changes in the formation and configuration of beaches are affected by regional geomorphology and type of available beach material (Don Wong, 1970). Short-term periodic changes, daily or seasonal, are due to the quantity of beach material available and the characteristics of waves supplying energy at the shoreline. Beaches remain stable only in areas where the supply of material brought into the littoral zone is equal to that removed (Zeigler, Tuttle, Giese and Tasha, 1964). Discussion of beach processes requires the use of shoreline terminology diagrammed in Figure 2-1.

Projecting headlands and shore bluffs of the north shore are the major sources of sediment supplied to the beach environment. Onshore movement of material from offshore portions of Long Island Sound is no doubt minimal (U.S. Army Corps of Engineers, 1969). We have found some cobbles with attached vegetation on the beaches after transport from offshore regions because of storm turbulence. Sand originally removed from some north-shore beaches during stormy weather and deposited in shallow water offshore gradually redeposits on these beaches during periods of calm weather. Long Island Sound acts as a barrier to any sediment delivered from the Connecticut shore by river transport.

Bluff deposits of the north shore consist of a heterogeneous mixture of glacial debris ranging in size from large boulders down to clay and silt. This debris is subject to the sorting action of winds and waves. The coarser material is concentrated as lag deposits in those sections of the environment subject to the most intense wave action (Evans, 1939; Bagnold, 1954; Ingle, 1966; and see Fig. 2-2). Gravel deposits are found in the foreshore zone because of selective transport along the breaker plunge line (the zone of maximum turbulence located immediately seaward of the swash zone) and on the berm as the result of storm activity and high tides. After removal from the beach deposit, fine sand, silt and clay are deposited in the quieter waters of offshore areas, tidal marshes, harbors and bays. Wind-winnowed sands stabilized by vegetation

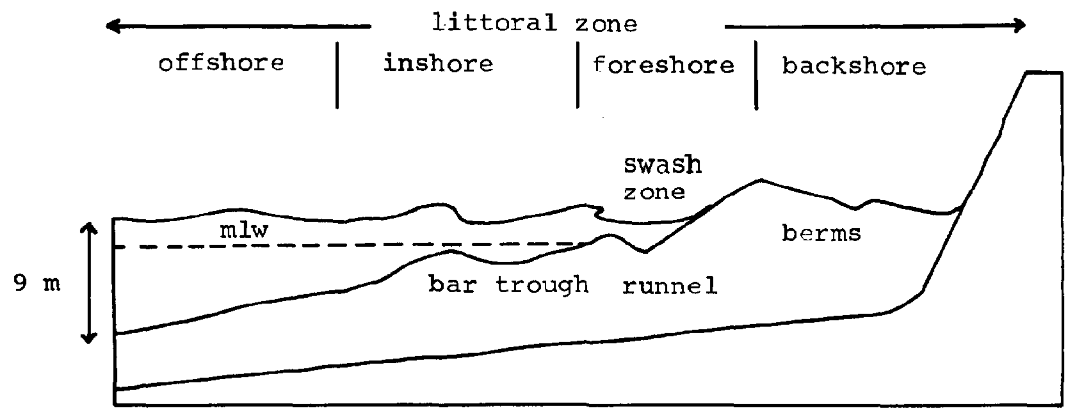

Fig. 2-1. Shoreline terminology (adapted from Ingle, 1966, p. 12).

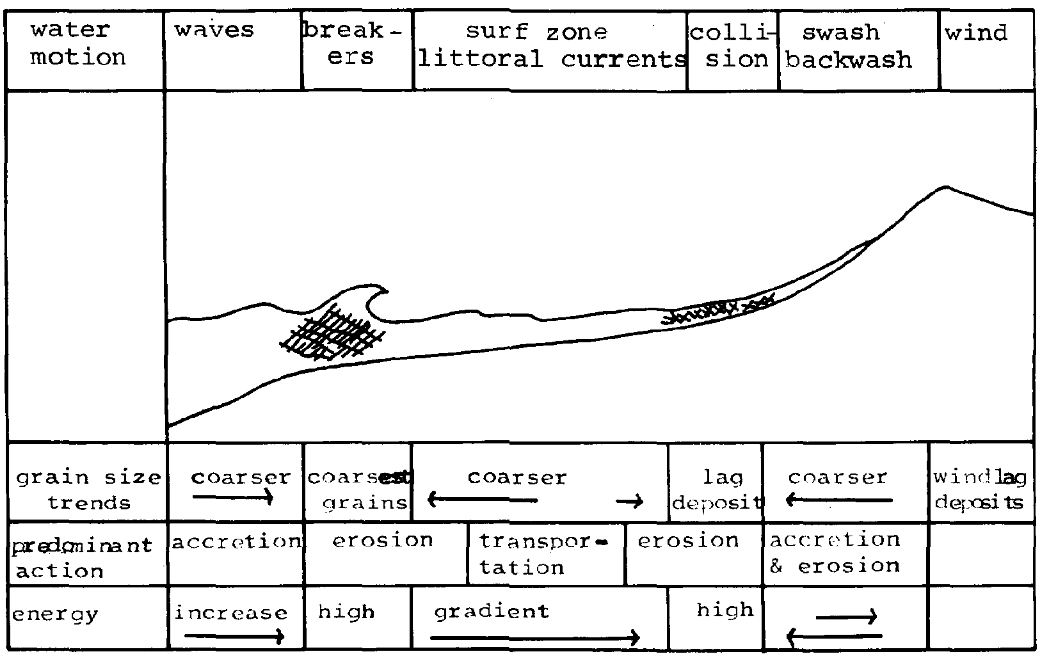

Fig. 2-2. Beach energy-sediment relationships (adapted from Ingle, 1966). Cross-hatched areas represent zones with high concentrations of suspended sediment.

have formed dunes at bar environments, and in some instances, at the base of stable bluffs. The data of Figure 2-2 summarize the energy-sediment environments associated with beaches.

B. Sea Level Changes

All coasts of the world have experienced some submergence since the last ice age (Shepard and Wanless, 1971). This submergence is probably a result of continental ice sheet melting and has played a major role in shaping the configuration of Long Island's shoreline. The maximal lowering of relative sea level - roughly 100 m - occurred approximately 20,000 years ago (Curray, 1965). At that time much of the continental shelf was exposed, and the shoreline was displaced roughly 139 km (86 miles) to the southeast of the present Long Island area (Uchupi, 1968).

During the last 3,000 years, sea level has risen at a very slow rate. Bloom and Stuiver (1963) found that submergence of the Connecticut coast occurred at the rate of 0.1 m (4 inches) per 100 years during this time period. This corresponds closely to Newmann's (1966) data for the western Long Island area. Both agree that sediment accumulation and salt marsh growth have been able to keep pace with submergence only during the last 3,000 years. Prior to that time, the higher rate of submergence prevented marsh development and maintained open lagoons and bays at the sites of the present marshes.

Data on historic changes of the position of mean sea level at selected points along the Atlantic coast have been obtained from tide observation stations maintained by the U.S. Coast and Geodetic Survey. Long-term records are needed to determine trends in relative sea level rise that would otherwise be masked by meteorologic effects on a short-term basis. Disney (1955) found that for the 60-year period from 1893 to 1953 mean sea level at New York City rose at the average rate of 3.3 mm per year, for a total change of about 20 cm (8 inches). During the period from 1940 to 1960, mean sea level for stations along the Atlantic coast rose at an average rate of 2.4 mm per year (Donn and Shaw, 1963). More recent observations suggest that there has been a marked increase in the rate of sea level rise during the last decade. During the period 1963 to 1970, sea level at Willets Point rose at an average rate of 12.5 mm per year, for a total rise of roughly 10 cm, or about 4 inches (Hicks, 1972). The above rates reflect both eustatic and tectonic effects on sea level change with the tectonic component being about 1.7 mm per year (Hicks, 1972). There appears to be a substantial increase in the eustatic rate of sea level rise in the last decade as compared to that observed earlier in this century.

It is impossible to relate erosion of Long Island's north shore quantitatively to changes in the position of mean sea level during the period of historic record. A rising sea level creates deeper water offshore. Waves would thus break closer to the beach zone. The greater amount of energy expended by the waves at the beach zone could lead to increased erosion (King, 1969, p. 299).

During the short time-span of human development and planning, small sea level changes would produce negligible effects on erosion of the north shore. However, if sea level continues to rise at the present rapid rate for an extended period of time, drastic changes in the erosion and accretion patterns of the north shore could be expected.

C. Waves

Wave data for the north shore of Long Island are not available (U.S. Army Corps of Engineers, 1969). Waves that affect the area are generated by local winds. Long Island and Block Island stop ocean swells from entering Long Island Sound. Northwest, north and northeast winds are responsible for the shallow-water waves of short period that hit the coast. The limited fetch lengths - "horizontal distance (in the direction of the wind) over which the wind blows" (U.S. Army Coastal Engineering Research Center, 1966, p. A-12) - and shallow areas in the Sound prevent build-up of large waves (Sanders and Ellis, 1961).

Northeast winds during storms are responsible for waves over 2 m (6.6 ft) high in western areas of the Sound. Hurricanes can produce even larger waves. The U.S. Army Corps of Engineers (1949) reported that waves 9 m (30 ft) high occurred at Bridgeport, Conn., during the hurricane of September 21, 1938. Most of the time, however, wave heights are small. At the Stratford Point light station on the Connecticut coast north of Port Jefferson, observations of wave height, direction and period were recorded during the three-year period from October 1954 to October 1957 (Helle, 1958). Figure 2-3 shows the distribution of wave heights during that period. Wave heights of 1.2 m (3.9 ft) or under occurred roughly 98 percent of the time. The maximum wave heights were roughly 3 m (10 ft), while wave periods ranged between 1.5 and 7.4 seconds. Although these data are not applicable to any particular point on the Long Island coast, they do indicate the nature of waves occurring in the Long Island Sound region.

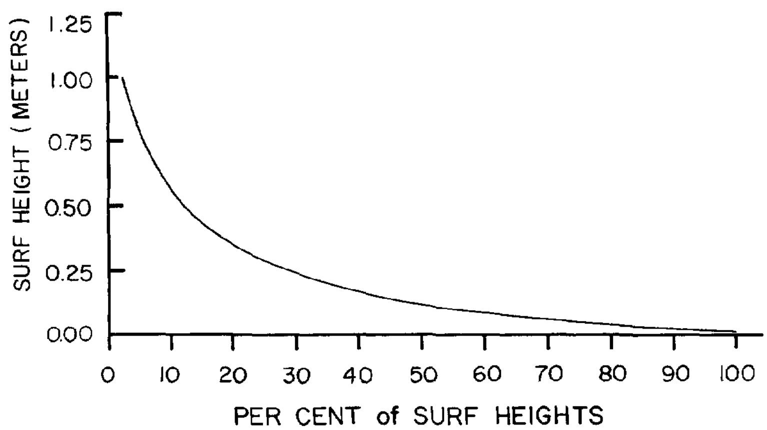

Fig. 2-3. Wave height frequency distribution, 1955-1957, Stratford Point, Connecticut. Adapted from tabular data of Helle (1958).

Beach profile development depends on wave and sediment characteristics. A large range in sediment grain size exists on the beaches of the north shore; given this sediment heterogeneity, beach profile development results largely from wave action (Ellis, 1962). Local winds create the waves in Long Island Sound. These waves have short periods, and hence they have large wave-height to wave-length ratios. This makes waves on Long Island Sound relatively steep. Steep waves are important agents of beach erosion as they tend to cause sediments to move offshore into deeper water, rather than alongshore as littoral drift (Don Wong,1970; U.S. Army Corps of Engineers, 1964). Saville (1950), Bascom (1951) and Scott (1954) have emphasized the importance of wave steepness in describing waves which tend to erode beach sediments and produce the so-called "storm beach" profile. Seasonal cycles of beach accretion in summer and beach erosion in winter that occur along the California coast (Shepard, 1963a) and along the barrier beaches of Long Island's south shore (Schuberth, 1972) have been related to wave steepness. Residents of the Sound Beach area have reported a cycle of beach sand depletion in winter followed by berm build-up in early summer. However, seasonal cycles do not occur at all locations along the north shore.

D. Tides and Tidal Currents

A brief discussion of the tides of Long Island Sound is found in Gross et al. (1972). The data of Table 2-1 show that tidal range increases from east to west. The zones of deposition and accretion associated with wave action migrate across the foreshore as the state of the tide changes (Duncan, 1964). Berm development takes place shoreward of the position of farthest advance of the swash-backwash zone (see Fig. 2-2).

In a study of Connecticut beaches, Ellis (1962) reported that tidal current velocities rapidly decreased as the shoreline was approached. He concluded that littoral drift was produced mainly by wave action. This is probably the case for much of the Long Island shore east of Port Jefferson. In contrast, under conditions of restricted flow such as at harbor entrances, tidal current velocities are greater and hence play a greater role in determining volume and direction of littoral drift. The greater tidal ranges at the western end of the Sound probably increase the influence of tidal currents on littoral drift.

E. Winds and Littoral Transport

Wind speed and direction are important factors in determining the rate of littoral transport. Littoral transport of sediment occurs as either beach drift

Table 2-1. TIDAL RANGES, NORTH SHORE, LONG ISLAND, NEW YORK[a]

Location	Tidal Range Mean m	(ft)	Spring m	(ft)
Willets Point	2.2	(7.1)	2.5	(8.3)
Execution Rock	2.2	(7.3)	2.6	(8.6)
Eatons Neck Point	2.2	(7.1)	2.5	(8.2)
Port Jefferson Harbor	2.0	(6.6)	2.3	(7.6)
Herod Point	1.8	(5.9)	2.0	(6.8)
Mattituck Inlet	1.5	(5.0)	1.8	(5.8)
Horton Point	1.2	(4.0)	1.4	(4.6)
Truman Beach	1.0	(3.4)	1.2	(3.9)
Orient Point	0.8	(2.5)	0.9	(3.0)

[a]U.S. Dept. of Commerce, 1971. Tide tables, east coast of North and South America. Washington, D.C. 290 p.

in the zone of uprush and backwash, as suspension load in the surf zone, or as bedload in the surf zone and offshore regions. The direction and rate of littoral transport depend mainly on the angle of wave approach, and wave energy at the shore, which in turn depend on the wind characteristics of the area (Saville and Watts, 1969). Other factors which influence littoral transport are the availability of sediment and its grain size distribution (Fairchild, 1966). Seasonal changes in wind direction produce variations in the direction of littoral transport. The net amount of littoral drift moving past a given point in one year is the net rate of littoral transport at that point (Saville and Watts, 1969).

Littoral transport is the sole initial supply of sediment to those sections of the north shore not backed by eroding bluffs. When the supply of sediment naturally brought to an area by littoral transport is blocked by a barrier, such as a groin or jetty, the beaches of that area will erode since they no longer receive sediment nourishment from updrift beaches. The littoral currents associated with the eroding beach have become "starved" in the sense that they tend to remove sediments without depositing material derived from upstream beaches. The narrow beaches at some of the projecting headlands of the north shore can be explained by vigorous littoral transport which removes more material than it delivers. This is often the case when littoral transport is split in two directions at the headlands (King, 1959). Littoral transport directions are thus important in determining the sand budget for a particular stretch of coast. The sand budget concept and its application to shoreline areas is discussed in Bowen and Inman (1966). A map of littoral transport directions for the north shore is shown in the fold-out map at the end of the report.

Fetch length is a limiting factor to the growth of wind waves in Long Island Sound. Wind direction and speed are important factors determining wave characteristics and, hence, littoral transport. Wind data for locations along Long Island's north shore are not available. However, long-term wind data from LaGuardia Field, New York, is probably representative of the wind conditions for the western Long Island region. Wind data can be used in conjunction with fetch lengths to determine the erosive potential of winds from different directions. Table 2-2 relates the percentage of total wind movement and duration from different directions to fetch lengths associated with waves capable of producing erosion at Old Field Point. Winds producing such waves occur about 55 percent of the time, and account for over 61 percent of total wind movement. Winds from the west-northwest, northwest and east-northeast (because of the relatively large fetch in the east-northeast direction) appear to have the most potential for creating erosive wave action at Old Field Point.

Severe Storms and Their Shoreline Effects

A. Types of Storms

Tropical cyclones and extratropical storms are important agents causing erosion and shoreline damage on Long Island's north shore. Extratropical storms, commonly referred to as northeasters, develop in the mid-latitudes in response to the interaction of warm and cool air masses.

B. Tropical Cyclone Frequency

On the basis of tropical cyclone tracks during the past 85 years, Simpson and Lawrence (1971) have determined the frequency of tropical cyclones entering 93 km (50 nautical miles) segments of the U.S. Gulf and Atlantic coasts. They categorized the North Atlantic tropical cyclones as follows:

1. tropical storms: tropical cyclones with sustained winds of at least 35 knots (40 mph),

Table 2-2. WIND CONDITIONS AND FETCH LENGTHS AT OLD FIELD POINT, NEW YORK[a]

Wind Direction	Percent Total Wind Movement, Per Year[b]	Percent Total Wind Duration, Per Year[b]	Fetch Distance (km) Old Field Point
W	4.9	5.2	46
WNW	13.5	10.9	28
NW	13.7	10.4	23
NNW	5.6	4.6	21
N	5.6	4.9	20
NNE	5.8	5.9	34
NE	8.3	8.8	44
ENE	4.3	4.8	97
E	1.5	2.9	--
ESE	0.9	1.9	--
SE	2.4	3.0	--
SSE	5.3	6.1	--
S	6.4	7.5	--
SSW	5.6	6.9	--
SW	8.3	9.0	--
WSW	7.9	7.2	--

[a]U.S. Army Corps of Engineers (1969, Appendix C).
[b]Data taken at LaGuardia Field, New York from 1949 to 1961.

2. hurricanes: tropical cyclones with sustained winds of at least 64 knots (73 mph), and

3. great hurricanes: tropical cyclones with sustained winds of at least 108 knots (125 mph). Great hurricanes cause severe coastal damage and are usually accompanied by a 3 to 4 m (10 - 13 ft) storm surge.

Figure 2-4 gives the probabilities that tropical storms, hurricanes or great hurricanes will occur in any one year for each of four 93 km (58 miles) coastal segments of the Long Island area. The probabilities are calculated from data given by Simpson and Lawrence (1971) on observed frequencies of tropical cyclones over the 85-year period 1886 to 1970. The frequency of tropical cyclones is greatest for the central portion of Long Island. Only one storm during the period of record occurred in the western Long Island area.

C. Extratropical Storm Frequency

In a study of storms which caused significant water damage along the Atlantic coastal margin of the United States during the period 1921 to 1962, Mather, Adams and Yoshioka (1965) determined that the recurrence interval of northeasters in the coastal areas of New York was about 1.2 years. For the Atlantic coast as a whole, northeasters were found to be frequent during the months of November (most frequent), March, October, February, December and January (least frequent). Also, storm frequencies over the period of record are marked by a distinct rise in recent years.

D. Storm Frequency Based on Shoreline Damage

The U.S. Army Corps of Engineers (1969) has reviewed literature on storm occurrences that have affected the segment of shoreline from central Maryland to the New Hampshire-Massachusetts state boundary. Storms passing through this region were believed to have either caused some degree of shoreline damage on Long Island or at least threatened the area. The storms were classified as hurricanes, extratropical storms and tropical storms. Categories were assigned to the storms on the basis of damage they inflicted on the shore areas of Long Island as follows:

Category	
A	unusually severe damage
B	severe damage
C	moderate damage
D	threatened area (no damage)

During the period 1635 to 1962 a total of 231 storms either threatened or did some degree of damage to the Long Island shore areas (Table 2-3).

Only 27 storms of all types were recorded from 1635 to 1800. Storm data during this time period is incomplete; however, the occurrence of storms that produced severe damage (Category A) has probably been well documented. Based on the 204 storms recorded for the period 1800 to 1962, we can state that the Long Island area experiences a storm which causes moderate damage about once every two years. Unusually severe storms occur, on the average, three times every century.

E. Storm Surge

Both tropical cyclones and extratropical storms produce storm surges, defined as the "difference between the observed water level and that which would have been expected at the same place in the absence of the storm" (Harris, 1963, p. 2).

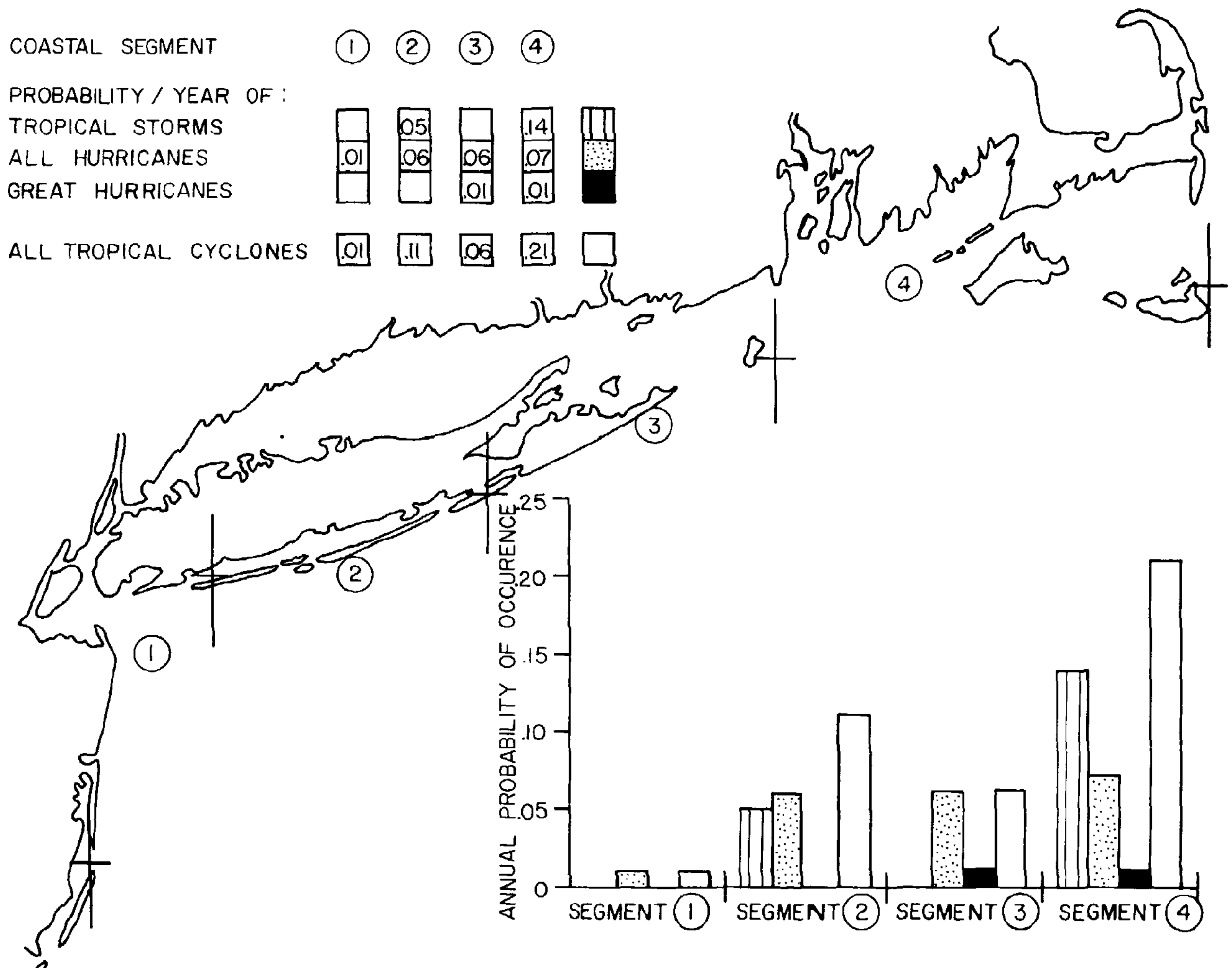

Fig. 2-4. Annual probabilities of tropical cyclones in coastal segments of the Long Island region; based on frequencies of cyclones from 1886 to 1970 compiled by Simpson and Lawrence (1971).

Table 2-3. HISTORY OF STORM OCCURRENCES, LONG ISLAND REGION. (U.S. Army Corps of Engineers, 1969)

Category	Storm Type	Occurrences in Time Intervals 1635-1962	1800-1962	1885-1962	Recurrence Intervals (years) 1800-1962	1885-1962
Unusually severe (A)	Hurricane	8	5	2		
	Tropical Storm	-	-	-	32.4	38.5
	Extratropical	-	-	-		
	Unknown	1	-	-		
	Total	9	5	2		
Severe (B)	Hurricane	9	7	6		
	Tropical storm	-	-	-		
	Extratropical	4	4	3	13.5	8.5
	Unknown	3	1	-		
	Total	16	12	9		
Moderate (C)	Hurricane	41	35	23		
	Tropical storm	3	2	2		
	Extratropical	35	35	37	2.1	1.2
	Unknown	8	5	1		
	Total	87	77	63		
Threatened the area (D)	Hurricane	46	41	31		
	Tropical storm	24	23	21		
	Extratropical	39	39	41	1.5	0.8
	Unknown	10	7	1		
	Total	119	110	94		
Total	Hurricane	104	88	62		
	Tropical storm	27	25	23		
	Extratropical	78	78	81		
	Unknown	22	13	2		
	Total	231	204	168		

The height of the surge associated with a particular storm depends, in part, on the following four processes:

1. The inverted barometer effect. The sea level surface is elevated in response to the low pressures associated with storms. In the open ocean, a pressure drop of 33.86 millibars of mercury (1 inch) will theoretically lead to a sea level elevation of 34 cm (13 inches) (Hobbs, 1970). In Long Island Sound, basin boundaries cause a decrease in the magnitude of this effect.

2. Wind set-up. Wind stress on the water surface will cause water levels to increase along the fetch in a downwind direction. Wind stress, and, hence, wind set-up are proportional to the square of the wind velocity. Wind set-up is also enhanced by decreasing depth (Harris, 1963). Easterly winds produce a large wind set-up effect in the western end of Long Island Sound.

3. Wave set-up. Breaking waves transport water into the near-shore zone, thus leading to increased height of the water level surface in this area. Wave set-up may account for as much as 1 to 2 m of storm surge height at a beach (Gentry, 1966). The effect is maximized by waves which break parallel to the coast (Harris, 1963).

4. Rainfall effect. Intense rainfall can lead to an increase of water levels, especially in estuaries.

Shoreline configuration plays an important role in modifying storm surge. In general, configurations which favor an increase in the range of astronomical tide will also favor an increase in storm surge heights.

Shoreline damage and erosion are often related to the maximum tides produced by a storm. Factors which determine the magnitude of storm surge in relation to mean high water are the stage of the astronomical tide, the intensity of the storm, the speed of storm movement, and the angle of the storm track at the shoreline (Hobbs, 1970). Tropical cyclones and northeasters produce different effects with regard to the latter three factors.

Tropical cyclones range in diameter from 80 to 800 km (50 to 500 miles). The strongest winds are located in a narrow band surrounding the center, or eye, of the storm (Tannehill, 1950). The barometric pressure of the eye is a good indicator of storm intensity (Harris, 1966); indeed, empirical relationships suggest that hurricane central pressure is the dominant factor determining storm surge (Hoover, 1957). Storm surge peaks and maximum wind velocities, however, are not found at the eye of the storm, but are displaced to the right of the storm track.

The wind pattern of tropical cyclones consists of a counterclockwise spiral. The winds in the right quadrants of this spiral are more or less parallel with, and reinforced by, the translational movement of the storm. This reinforcement can be of considerable magnitude, as hurricanes have travelled at forward speeds of over 50 knots (58 mph). Wind and wave set-up are at a maximum in the right, or "dangerous" half of tropical cyclones (Hall, 1939). South-facing coasts that are aligned perpendicular to storm tracks receive the full impact of the reinforced winds and wave set-up. North-facing coasts are somewhat protected. This is one reason why the Connecticut coast of Long Island Sound usually experiences surges of greater magnitude than the northern Long Island coast. Another factor is the build-up of water along the Connecticut coast because of the effect of Coriolis acceleration on currents directed into the Sound from east to west. If the storm track passes to the right of a coast, wind and waves will be directed in an offshore direction, thus minimizing shore damage due to tidal flooding (Hobbs, 1970). The winds to the left of the storm track are also weaker than those to the right, in that the winds blow in directions opposite to the translational movement of the storm.

The dominant effect of shoreline orientation on storm surge can be seen by comparing the storm tracks of the major damage-producing hurricanes of the Long Island Sound region as shown in Figure 2-5. The hurricanes of September 21, 1938 and August 31, 1954 travelled in paths perpendicular to the shoreline. Figure 2-6 shows the surge heights produced by these two storms across the middle of Long Island Sound. (Surge heights in the shallow bays along the coast were considerably amplified, as shown in Table 2-4). The 1938 hurricane produced record tides for both the eastern and western ends of the Sound. In the central section, the profiles of both storms coincided with each other, but they are of record height here also. Data from tide observations suggest that a portion of the surge of such storms hits the New England coast near Rhode Island, and that the surge wave travels from east to west through Long Island Sound (Harris, 1963; Hall, 1939). The height of the storm surge decreases in the wide, central section of Long Island Sound, but increases in height as the Sound narrows near its western end as is shown in Figure 2-6. There is a lag of about two hours between the time of storm passage and the time of maximal tidal height at Willets Point.

Extratropical cyclones are about three times as large as tropical cyclones (Byers, 1959), though pressure gradients and hence, wind velocities of extratropical storms are lower than those associated with tropical cyclones. Gusts of hurricane velocity, however, have been associated with northeasters (Brumbach, 1965). Wind patterns of northeasters form a counterclockwise spiral directed toward the center of low barometric pressure. Wind directions from such storms at a particular area depend on the relative position of the storm track (Zeigler, Hayes and Tuttle, 1959). When a storm center passes to the west of the Long Island Sound area, winds initially blow from the east or southeast. As storm movement progresses, the winds shift to a southerly and then a westerly direction. This type of storm results in offshore winds for the north shore of Long Island. Wave action on the coast is then minimal. If, however, the storm center passes to the east of the Sound, the initial winds blow from the northeast. At a later time, the winds veer to the north and northwest. This type of storm produces onshore winds along the north shore, leading to increased wave height wind set-up in the area.

The effect of northeasters on shoreline areas often depends on their speed of forward movement. If the storm progresses rapidly, variable wind directions over a given fetch length prevent the build-up of large storm waves. However, if storm progress is delayed by ridges of high pressure, winds from a particular direction have time enough to act on a given wave group, so as to produce waves of maximum height for a specific wind velocity and fetch length (Burt, 1958; Darrielsen, Burt and Rattray, 1957). The wave heights on an open coast produced by a stationary northeaster of sufficient intensity may equal or exceed those produced by many tropical cyclones. Thus northeasters with easterly winds of long duration have the most effect in the Long Island Sound region.

The severe winds and extreme tides of tropical cyclones usually last less than six hours (Gentry, 1966). The wind and wave effects of extratropical cyclones, though perhaps less severe, can last up to four or five tidal cycles. Prolonged attack on an eroding beach during successive high tides can lead to substantial dune and bluff recession (Hayes and Boothroyd, 1969; Hayes, 1967).

F. Storms as Geologic Agents

Hurricanes and northeasters have played important roles in the modification of the shoreline. The present Long Island shoreline is, in fact, mainly the result of erosion and deposition caused by these storms. A severe northeaster

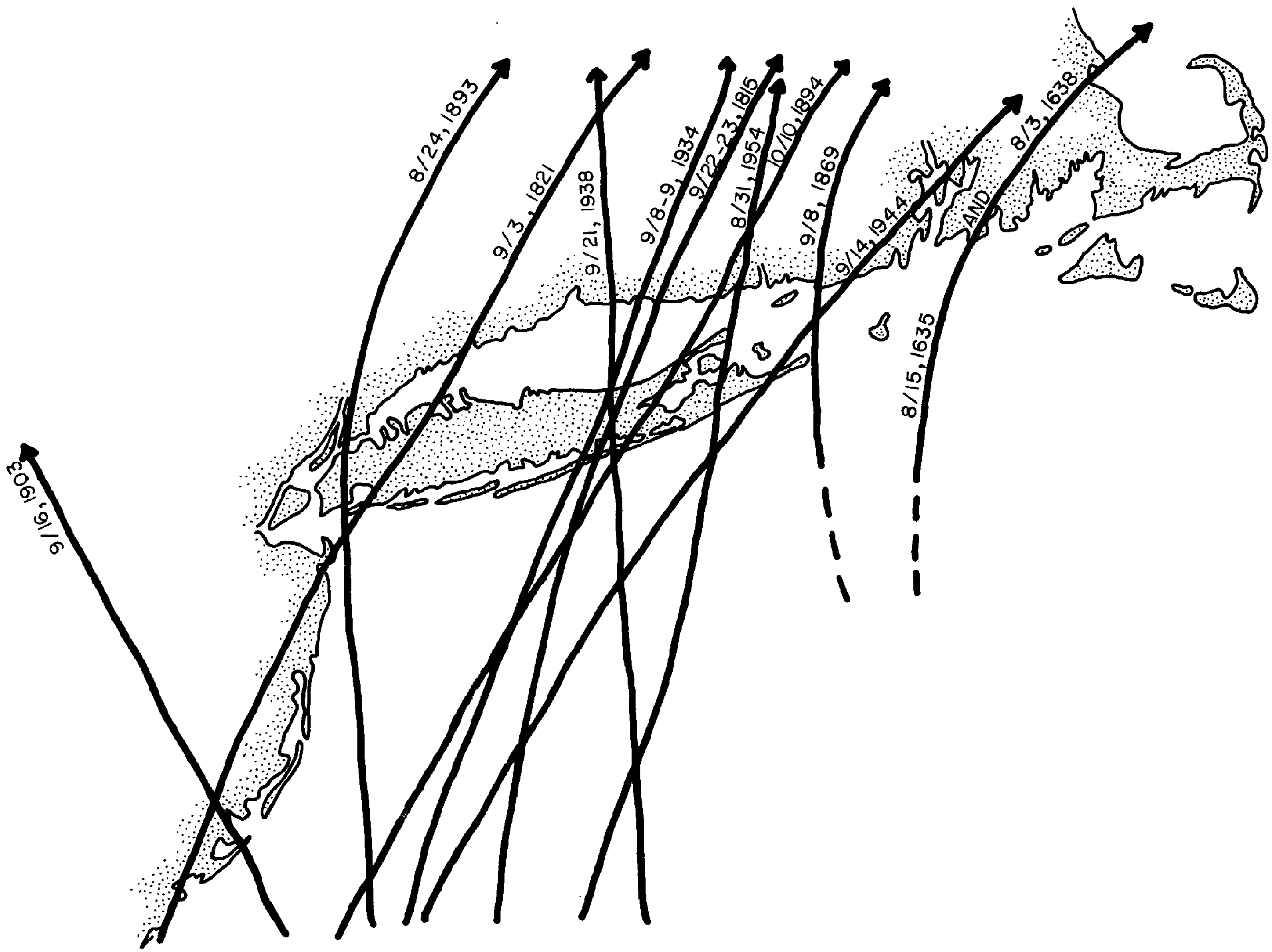

Fig. 2-5. Tracks of major hurricanes in the Long Island area. The many sources of information for these tracks are cited in Davies (1972, Table 4).

Table 2-4. STORM SURGE HEIGHTS, HURRICANES OF SEPT. 21, 1938 AND AUG. 31, 1954, NORTH SHORE OF LONG ISLAND, NEW YORK

Location	Sept. 21, 1938 height above mean sea level		Aug. 31, 1954 height above mean sea level	
	m	(ft)	m	(ft)
Willets Point	3.9	(12.9)	3.5	(11.4)[b]
Port Washington	4.4	(14.3)	3.6	(11.7)[c]
Roslyn	3.7	(12.1)	3.4	(11.0)[c]
Oyster Bay	3.4	(11.2)		
Huntington Harbor	3.1	(10.1)		
Port Jefferson Harbor	2.5	(8.2)	2.9	(9.45)[b]
Mattituck Inlet	2.4	(7.8)		
Orient Point	2.2	(7.1)	2.6	(8.4)[b]

[a] Bigwood, B., A. Harrington, O. Hartwell, and H. Kinnison. 1940. Hurricane Floods of September 1938. U.S. Geol. Survey Water Supply Paper 867. p. 523.

[b] U.S. Army Corps of Engineers (1969).

[c] Harris (1963).

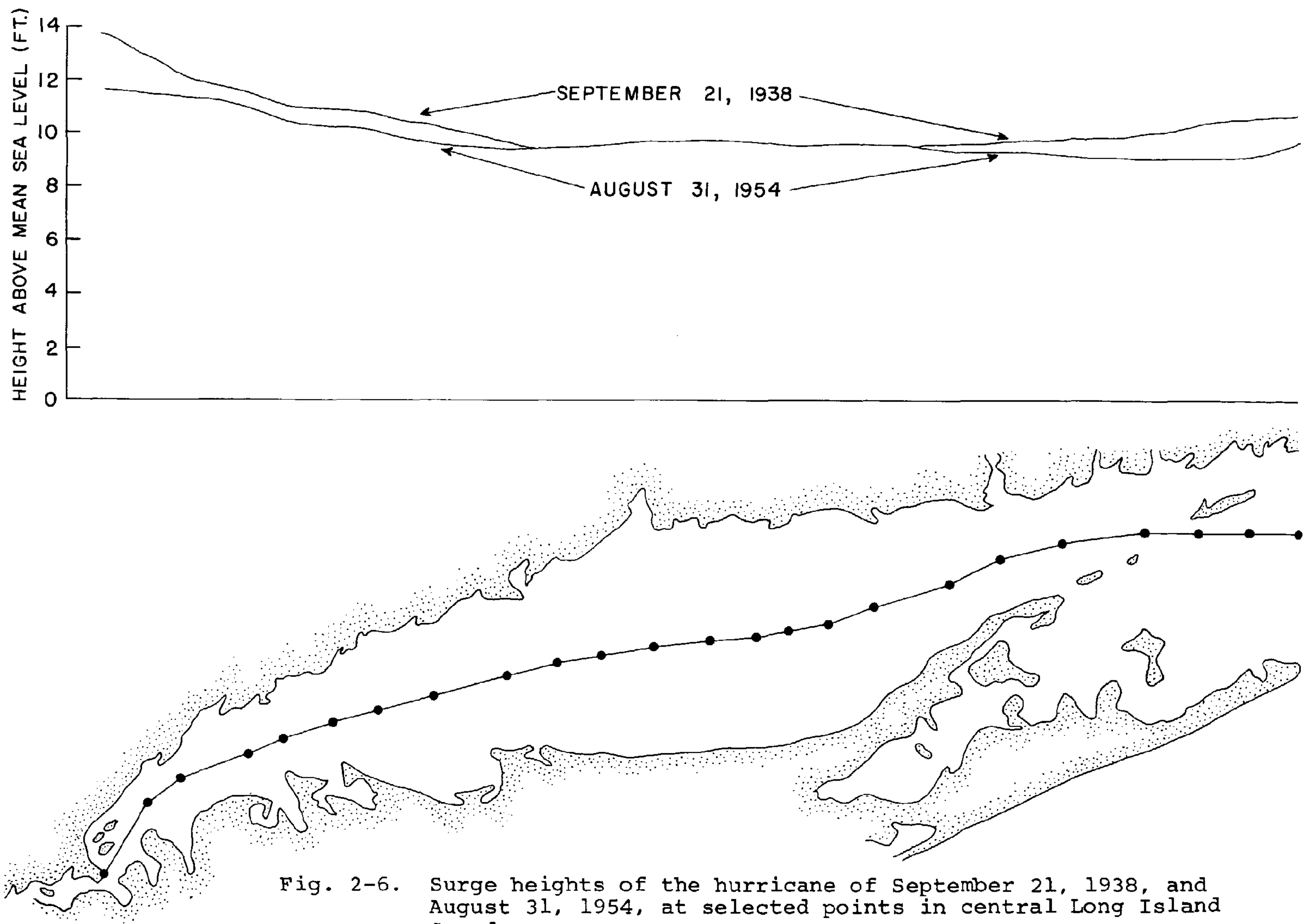

Fig. 2-6. Surge heights of the hurricane of September 21, 1938, and August 31, 1954, at selected points in central Long Island Sound.

or a hurricane can cause as much damage to the shore in a matter of a few hours as it would take normal weather conditions to produce in a hundred years. Observations indicate that "most energy is expended in present-day nearshore marine environments, not in a uniform constant manner but rather in sporadic bursts, or spurts, as a series of minor catastrophes" (Hayes, 1967, p. 52). Such a catastrophe occurred on September 21, 1938. In a few hours the storm surge of this hurricane levelled 6 m (19 ft) dunes on the Rhode Island coast that had been building up since the occurrence of a hurricane of similar magnitude on September 22, 1815 (Brown, 1939). The 1938 hurricane also caused glacial cliffs 15 m (48 ft) in height to recede over 10 m (33 ft).

Investigators of beaches in the New England area (Zeigler, Hayes and Tuttle, 1959; Hayes and Boothroyd, 1969) have concluded that beach profile development is largely the result of the severity and frequency of storms affecting the area within the previous few months. Storm activity does not necessarily cause all beaches to erode; that is, wind direction and coastal configuration can cause littoral drift to accumulate in areas downstream from those that are eroding (Zeigler, Hayes and Tuttle, 1959).

The effects of the northeaster differ from those of hurricanes in that the latter produce higher tides. However, northeasters are much more frequent than hurricanes, and the combined effect of two or more storms in a short period of time on beaches that have not achieved full post-storm beach build-up can be just as devastating. Therefore, similar shoreline changes can be expected from a hurricane, a severe northeaster, or several northeasters occurring in a short time interval. However, the magnitude of the changes will probably be larger in the instance of severe hurricanes as tidal inundation is the main cause of shoreline damage (Freeman, Baer and Jung, 1957).

The impact of the September 21, 1938 and the September 14, 1944 hurricanes on shores in the Long Island region has been well documented (Nichols and Marston, 1939; Howard, 1939; Brown, 1939; Chute, 1946). These studies indicate that there will be differing results of severe storms for different shore environments. Two main types of shore environment are found on Long Island's north shore; bluffed coasts and bar beaches. Bluffed coasts are primarily erosion features, while bar beaches, which include spits, baymouth bars and tombolos, are primarily depositional formations. The effects of hurricane attack on these two environments are outlined in Table 2-5. The most dramatic changes - dune and bluff erosion and inlet formation - are the result of the storm surge, which for a period of only a few hours essentially creates a new shoreline of submergence in areas not normally exposed to direct wave and tidal action (Brown, 1939). Figure 2-7 shows the sequence of changes in profile development that would most likely occur on Long Island's north shore as the result of hurricane activity.

Chute (1946) studied bluff recession along the southern Cape Cod coast caused by the hurricane of September 14, 1944. The magnitude of cliff recession was found to be related to several shoreline characteristics:

1. Virtually no cliff recession occurred in those areas where the beach was at least 42 m (138 ft) wide. Smaller beach widths were associated with cliffs that retreated up to 15 m (48 ft) as a result of the storm. The wider beaches were effective in absorbing wave energy.
2. High bluffs receded less than low bluffs. Given the same length of recession, more debris will slump to the base of a high bluff than a lower bluff. Therefore, more material must be removed by wave action at the base of the high bluffs in order for additional recession to occur.

Table 2-5. GEOLOGIC EFFECTS OF HURRICANES ON LONG ISLAND'S NORTH SHORE

Shore Environment	
Bluffed Coast	Bar Beach
1. Beach recession. The mean high water line migrates landward as beach deposits are removed and transported to near-shore bars.	1. Beach recession. The mean high water line migrates landward as beach deposits are removed and transported to near-shore bars. A low flat "hurricane beach profile" develops.
2. Bluff recession. Bluff and headland erosion due to direct wave attack occurs during the peak of the surge flood.	2. Dune erosion. Dune scarps are formed as a result of wave attack. Overtopping occurs during extreme surges.
3. Formation of wave-cut bench and wave-built bench. Beach is widened by formation of the wave-cut bench. Material eroded from the bluff is deposited on the beach face, and in some instances, raises beach elevation above pre-storm values.	3. Inlet formation. Beach lowering leads to inlet formation, especially during ebb flow of storm tide.
	4. Deposition of tidal deltas and overwash fans. Beach and dune sands are deposited in the bays and on the tidal marshes, thus leading to increased bar width.

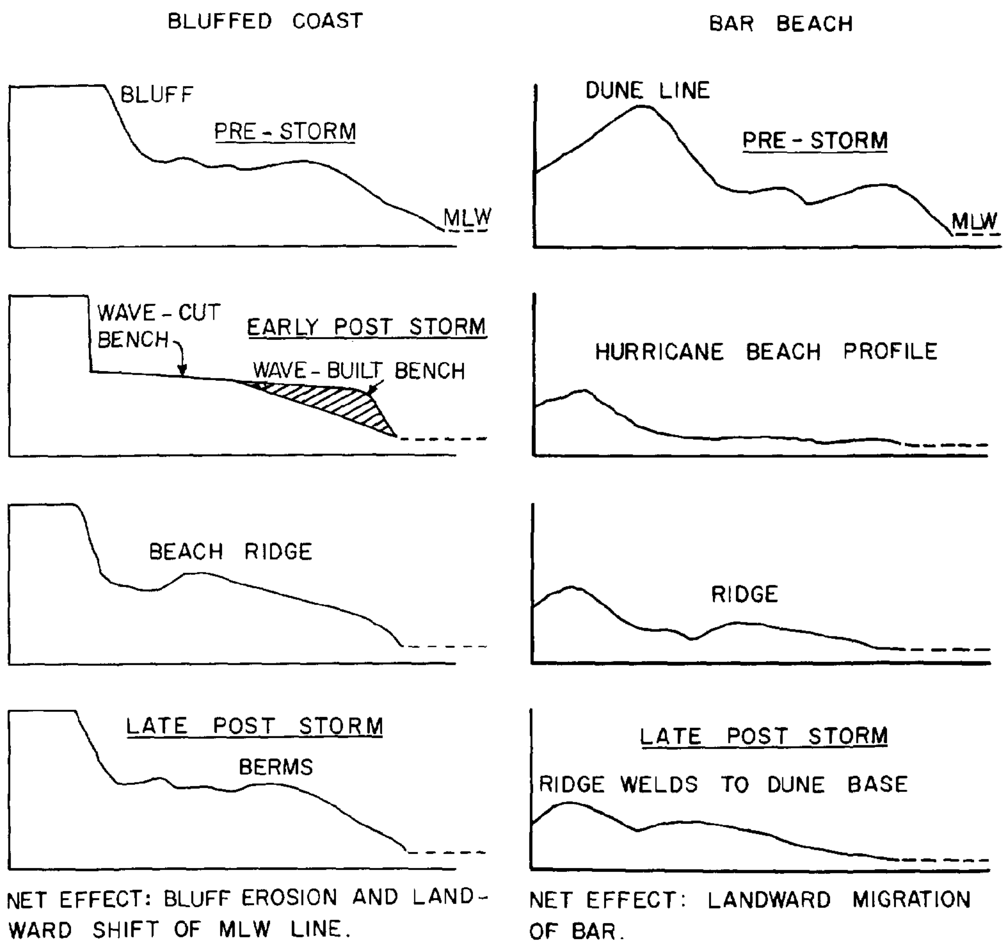

Fig. 2-7. Expected beach profile changes due to hurricane occurrence.

3. The presence of vegetation and dune ridges at the bases of the bluffs retarded bluff erosion.

4. Bluffs composed of till and clay were more resistant to wave attack than those composed primarily of sands.

5. Seawalls were ineffective in curtailing bluff erosion unless they were constructed heavily enough to withstand the forces of direct wave impact and they extended to a height greater than that achieved by the storm surge.

Clearly, these general findings also apply to the north shore of Long Island. Bluffs fronted by wide beaches tend to erode less than those fronted by narrow beaches. Under the same conditions of wave attack, a high bluff would be cut back less than a low bluff. Vegetation stabilizing the bluff face also tends to retard erosion.

Howard (1939) and Nichols and Marston (1939) found that inlets formed in those sections of bars which were narrow and low in elevation. Also, large areas of the bars were completely inundated at the peak of the storm surge. High storm surges have a devastating effect on the north shore because of human development on the bar formations.

The shoreline has a remarkable ability to restore itself to its pre-storm condition (Nichols, 1967). Shoreline features are controlled by average, long-term steady state conditions (Zeigler et al., 1964). Chute (1946) found that some of the material eroded from the bluffs was deposited on the beach in the form of a wave-built bench. In some instances, this deposition caused up to a 1.2 m (4 ft) increase in beach elevation in backshore areas as compared to pre-storm values. Some material is eventually restored to the beaches from the near-shore bars. Therefore, the net effect of a severe storm on the bluffed coast of the north shore is bluff recession and landward shift of the mean high water line (see Fig. 2-7). Bar beaches become wider and flatter. The berms on the beaches gradually build up a convex profile. The dunes, however, require many years to build up to their former heights, and this process is often slowed by human interference.

G. Bluff Erosion

Over long periods of time, bluff and dune recession will correspond with the recession of the high water shoreline. As mentioned earlier, dunes can erode or accrete, while bluffs can only erode or remain stable. Over short time spans (i.e. on the order of decades) bluff recession does not necessarily correspond with movement of the high water shoreline. Sediment derived from an eroding bluff can be deposited on the beach, resulting in accretion of the berm and no change in position of the high water shoreline.

Studies of the bluff erosion on the Oregon coast (Byrne, 1963; North and Byrne, 1965) indicated that landslide frequency correlated well with periods of high wave activity and heavy precipitation. Kaye (1967) found that rainwash and mass wastage (the sloughing off of soil sheets because of differential ice melting) were the chief causes of erosion of a glacial cliff in Boston Harbor. On the Long Island coast, direct wave attack, precipitation, ground water movement in the form of spring discharge, and ice thaw seem to be responsible for bluff recession.

Wave attack can either cut the bluff face directly, or act to prevent the accumulation of a talus zone that would otherwise bury the cliff face and retard erosion. In addition to their high tides and winds, tropical cyclones are usually accompanied by intense precipitation which increases their erosive potential.

In August 1955, 37 cm (15 inches) of rain fell at Mineola during a 33-hour period. The recurrence interval of this storm (hurricane Connie), based on its rain intensity, is over 100 years (Miller and Frederick, 1969).

A major storm can cause as much bluff erosion in a single day as the"normal" weather processes have in a number of years. As an example of such action, the hurricane of September 14, 1944 cut the bluffs back at Shoreham a horizontal distance of over 12 m (39 ft),while creating a vertical cliff 3.3 m (10.8 ft) in height (Joint Legislative Committee . . . , 1947).

Chapter 3

COASTAL INVENTORY

General Shoreline Trends and Processes

Important features of the north shore of Nassau and Suffolk Counties are summarized on large-scale base maps, each covering three to seven miles of shoreline. Station locations, rates of shoreline erosion (E) or accretion (A), and extent of the flood plain (stippled areas) are given on six base maps for Nassau (Figs. 3-1 to 3-6) and 24 for Suffolk (Figs. 3-7 to 3-30). Villages, major roads, and waterways are also shown. The fold-out map at the end of the report gives the location and figure number for each base map. Stations included within the base maps are also indicated on the fold-out map.

Shoreline length for the north shore, the south shore, the eastern shores of the Peconic Bays, and the various islands associated with the Peconics is given in Table 3-1.

Annual shoreline erosion and accretion rates are indicated on the base maps in feet per year, averaged over the 80-year period 1885 to 1965. For Suffolk County the average erosion (E) or accretion (A) between two stations is listed. For Nassau County, because the same resources were not available (see Methods, page 90), the erosion-accretion rates at stations were determined. However, we believe the location and number of stations suffice for prediction of the trend between most stations. Erosion-accretion rates for all stations are given in Figure 3-31, and indices of erosion or accretion are given in the Beach Utility Index, Table 3-5.

We examined possible correlation of erosion-accretion rates with other parameters, such as foreshore beach width and grain size. However, no evidence of consistent relationships could be found.

The flood plain is the stippled region on each base map. The entire flood plain is subject to inundation during a standard project hurricane. A standard project hurricane is defined as a "hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations" (U.S. Army Coastal Engineering Research Center, 1966, p. A-17). The number of structures in the flood plain is listed by township in Table 3-2.

We were able to determine bluff recession rates for seven locations, in addition to data previously obtained by other investigators (Table 3-3). The locations of bluffs and dunes, as well as bluff heights, are listed as part of the Beach Utility Index (Table 3-5).

Beach Trends and Processes

Grain size analysis (usually for both foreshore and backshore sand samples) was performed for 79 stations. Median grain size, 16th percentile grain size, and 84th percentile grain size* are shown in Figure 3-32 for the forebeach and in Figure 3-33 for the backbeach. Approximate grain size is also shown in the Beach Utility Index (Table 3-5).

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*Sixteen, 50, and 85 percent of the particles are smaller than the 16th percentile grain size, median grain, and 84th percentile grain size, respectively.

The grain size of north shore beaches is determined by the effects of waves and winds on glacial deposits from the ice age. Eroding bluffs also contribute sediment to the beach, although much of the material may be too coarse to be moved from the base of the bluff (except at storm tides) or may be too fine to remain on the beach (see Fig. 3-34 for bluff grain size).

Profiles of the beach perpendicular to the shoreline were taken for 80 stations. Though the profiles have not been incorporated in this study, the beach widths* are shown in Figure 3-35 and in the Beach Utility Index.

Protection Measures

A. Engineered Structures

The purpose of groins (Fig. 3-36) is to retard sand movement or erosion. However, "on the Jersey coast, where groins have been used extensively, it is estimated that they have reduced the rate of sand movement by about 12 percent" (Gross, 1972, p. 384). Groins can effectively save a beach on one side but cause extensive erosion on the other side (Fig. 3-36).

Jetties are designed to prevent shoaling of a channel. Unfortunately, they often cause accretion updrift of the channel and erosion downdrift of it, as illustrated in Figure 3-37.

Bulkheads (Fig. 3-38) are designed to prevent loss of land, while seawalls (Fig. 3-39) are designed to prevent waves from damaging upland features.

Groins, jetties, piers, seawalls and bulkheads are subject to wave action and typically require continual maintenance to prevent their deterioration. In 1965, 55 percent of the groins in Suffolk County were in poor condition (Table 3-2). The percentage is probably higher now (1973).

An inventory of the above structures in Suffolk County by township is given in Table 3-2. For an extensive treatment of the planning and design of protection structures, consult U.S. Army Coastal Engineering Research Center (1966).

B. Vegetation and Terracing

Vegetation and terracing are important measures of bluff erosion control, but to protect the bluff from direct wave attack (Fig. 3-40), bulkheading is also necessary.

Wildwood State Park (Station 113) has essentially eliminated bluff erosion (Table 3-4). This has cut off a source of sand for the adjoining beach, which probably accounts for its narrow width and high rate of shoreline erosion (see Beach Utility Index).

For further discussion of vegetation and terracing techniques, consult the New York State Cooperative Extension Service, Agricultural Division, 246 Griffing Avenue, Riverhead, N.Y. 11901, and How to Hold Up a Bank by Giorgina Reid (1969).

Beach Utility Index

The Beach Utility Index (Table 3-5) comprises six separate characteristics. The numbers associated with each characteristic are defined in Table 3-4. Number "1" represents the optimal state with successively higher numbers representing conditions further and further from the ideal. Typical applications of the utility index are discussed in Chapter 4.

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*Beach width is defined as the distance from the mean high tide line to the base of a bluff, dune or structure, such as a road.

Table 3-1. LONG ISLAND SHORELINE

	km*	statute miles
NORTH SHORE	342.6	213.0
Nassau County	87.5	54.4
North Hempstead	45.8	28.5
Oyster Bay	41.7	25.9
Suffolk County	255.1	158.6
Huntington	107.4	66.8
Smithtown	23.1	14.3
Brookhaven	63.0	39.2
Riverhead	23.2	14.4
Southold	38.4	23.9
SOUTH SHORE	176.4	109.6
Nassau County	28.7	17.9
Oyster Bay	4.8	3.0
Hempstead	23.9	14.9
Suffolk County	147.7	91.7
Brookhaven	36.9	22.9
East Hampton	37.7	23.4
Southampton	43.7	27.2
Islip	10.5	6.5
Babylon	18.9	11.7
EASTERN FORKS	201.6	125.3
Southold	81.6	50.7
Riverhead	8.2	5.1
Southampton	54.0	33.6
East Hampton	57.8	35.9
ISLANDS	107.8	67.0
Shelter Island	36.1	22.4
Fishers Island	31.0	19.3
Gardiners Island	23.5	14.6
Plum Island	11.2	7.0
Robins Island	6.0	3.7

* 1 km = .6214 statute miles

Table 3-2. NUMBER OF STRUCTURES ON FLOOD PLAIN OF THE NORTHERN SHORE.

Township	Number of Houses[c]	Number of Groins[a,b]	Number of Jetties[a,b]	Number of Seawalls, Bulkheads, and Revetments[a,b]
North Hempstead	29	-	-	-
Oyster Bay	226	-	-	-
Huntington	22	135 (83)	5 (2)	62 (7)
Smithtown	23	10 (5)	0 (0)	5 (1)
Brookhaven	190	26 (11)	6 (1)	29 (2)
Riverhead	71	26 (10)	0 (0)	26 (0)
Southold	152	40 (22)	3 (0)	15 (2)

[a]Numbers in parentheses indicate structures in poor condition.

[b]U.S. Army Corps of Engineers (1969), from field surveys taken in 1965.

[c]Houses counted on 1970 aerial photographs.

Table 3-3. BLUFF RECESSION RATES, NORTH SHORE, LONG ISLAND, N.Y.

Location	Period of Record	Recession Rate (m/yr)	(ft/yr)
Oak Neck Point	1915-1922[a]	0.3	1.0
East Fort Point	1833-1883[a]	0.9	3.0
Eatons Neck	1933-1966[b]	0.5	1.6
West Fort Salonga	1933-1966	0.5	1.6
Crane Neck Point	1911-1945[c]	0.8	2.6
Old Field Point	1933-1966[b]	1.6	5.2
	1911-1945[c]	0.8	2.6
	1886-1955[d]	0.3	1.0
Belle Terre	1933-1961[b]	0.3	1.0
	1933-1966	0.2	0.8
Miller Place	1948-1955[d]	0.6	2.0
Rocky Point	1933-1966	0.2	0.8
Wading River	1933-1966	0.5	1.6
Wildwood State Park	1933-1966	0.0	0.0
Oregon Hills	1933-1966	0.5	1.6
Horton Point	1933-1966	0.2	0.5
	1933-1960[b]	0.5	1.6
Mulford Point	1933-1960[b]	0.3	1.0
0.7 mi. west of Orient Point	1933-1960[b]	0.6	2.0

[a]Johnson (1925).

[b]McClimans, R. J. 1970. Suffolk County bluff and shore recession. U.S. Department of Agriculture, Soil Conservation Service, Riverhead, New York. Unpublished manuscript. 2 p.

[c]Joint Legislative Committee Studying the Problems of Checking Erosion along the North Shore of Long Island (1947).

[d]U.S. Army Corps of Engineers (1969), Appendix L.

Table 3-4. MEANING OF BEACH UTILITY INDEX NUMBERS FOR EACH CHARACTERISTIC

Index Number*	Natural Protection Barriers* (Elevation in Feet)	Shoreline Erosion (E)/Accretion (A) (ft/yr)	Beach Width (ft)	Foreshore Median Grain Size (mm)	Backshore Median Grain Size (mm)	Beach Access
1	Bluff: 150	> 0.4A	> 150	< 2.0	< 2.0	Extensive Parking
2	Bluff: 101-150	0.4A-0E	126-150	2.0-3.9	2.0-3.9	Limited Parking
3	Bluff: 51-100	0.1E-0.5E	101-125	4-7.9	4-7.9	Public Road
4	Bluff: 11-50	0.6E-1.0E	76-100	8-15.9	8-15.9	Restricted Governmental Road
5	Bluff: ≤ 10 or Dune	1.1E-1.5E	51-75	16-31.9	16-31.9	Private Road
6	No Bluff or Dune	1.6E-2.0E	26-50	32-63.9	32-63.9	Walking Only
7		> 2.0E	1-25	≥ 64	≥ 64	
8			No Beach			

*A "d" following an index number for natural protection barriers indicates the presence of a dune seaward of a bluff.

Table 3-5 BEACH UTILITY INDEX (Definitions of the index numbers in Table 3-4)

Station Number*	Natural Protection Barriers	Shoreline Erosion-Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
1	4	4	8			
2	4	4				
3	4	4				
4	5	5	8			
5	6	1				
6	4	2	8			
7	5	2	7	4	1	5
8	5	2				
9	5	3	7	4	1	3
10	5	5				
11	5	3				
12	5	2				
13	5	2				
14	6	4				
15	6	4				
16	6	5				
17	3	4	7	1	1	2
18	3	2				
19	5	4				
20	4	3	3	4	4	6
21	3	2				
22	3	1				
23	4	2				
24	4	5				
25	4	4				

*Locations of stations are shown in the fold-out map at the end of the report.

Table 3-5 BEACH UTILITY INDEX, continued

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
26	5	2				
27	5	4				
28	6	4				
29	5	1				
30	4	2	6	4	1	6
31	5	3	8			3
32	5	4	8			3
33	6	4	6	3	2	1
34	6	2	5	3	3	3
35	6	1	5	5	5	3
36	4	1	7	7	7	3
37	4	7	7			
38	4	4	6	4	3	3
39	6	*				
40	6	*	7	3	4	3
41	5	*				
42	5	*	6	4	1	2
43	4	7				
44	5	1	7		6	3
45	4	7				
46	5	2	7	3	1	5
47	4	4	7		2	3
48	5	5	6		3	5
49	5	3				
50	6	4	7	7	7	3

*See Addendum I.

Table 3-5 BEACH UTILITY INDEX (con't.)

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
51	6	1		6	4	6
52	5	1	1	4	3	4
53	5		1	4	6	4
54	6	4				
55	3	5	5	5	4	6
56	4	4				
57	5d	2	4	2	1	4
58	4	3	6	7	4	6
59	4	5	6	7	4	6
60	6	3				
61	3	4	7	5	4	5
62	6	5	4	5	4	4
63	5	7	6	7	1	4
64	4	4	6	7	3	4
65	4	4				
66	6	2	4	4	2	3
67	5	4				
68	5	2	2		1	3
69	5	5				
70	4	2	4	1	2	3
71	5	5				
72	4	1	3	4	2	1
73	4	7				
74	5	7	4	7	6	5
75	3	7	4	7	1	3

Table 3-5 BEACH UTILITY INDEX (con't.)

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
76	3	7				
77	6	7	1	4	1	1
78	6	2	3	3	1	1
79	5	2	6	1	1	1
80	4	2				
81	3		6	4	5	6
82	6	1	1	5	2	1
83	6	2	5	4	4	1
84	3d	7				
85	3d	6	5	5	1	4
86	3d	4	7	7	5	6
87	6	5	4	5	6	5
88	5	5	4	6	3	5
89	5	5				
90	4	3	6	6		6
91	5	6	4	4	3	6
92	5	1	3			
93	2	4	5	5	5	6
94	2	2				
95	3d	3	2	3	5	6
96	3		2	5	5	6
97	5	7	2	4	4	3
98	6	2				
99	4	2				
100	2	5	5	4	4	6

Table 3-5 BEACH UTILITY INDEX (con't.)

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
101	3d	5	5	4	1	3
102	4	6	4	4	2	2
103	4	5	5	5	6	3
104	3d	4	5	5	5	3
105	2	6				
106	4d	4	3	4	3	5
107	5	5				
108	5	2				
109	6	1	7	6	1	2
110	2d	5	7	5	2	3
111	4d	6				
112	4	3	7	4	5	3
113	3	6	7	4	4	4
114	3d	5	7	1	1	3
115	2	6	7	6	1	5
116	1	7				
117	2	3	7	4	6	6
118	3	7				
119	2	6				
120	3	5	6	7	6	5
121	2	6				
122	2	7				
123	4	7				
124	6	4	4	3	4	1
125	3	5				

Table 3-5 BEACH UTILITY INDEX (con't.)

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
126	3	4				
127	2	3				
128	6	1	4	5	5	3
129	5	7	6	5	5	3
130	3	4				
131	3	4				
132	3	3	6	7	6	2
133	3	4				
134	4	5				
135	6		1	5	5	2
136	6	6	6	4	5	3
137	6	7				
138	6	6	3	3	4	1
139	3	4	4	4	7	3
140	6		6	4	4	3
141	6	1	6	5	5	2
142	4	1				
143	4	2				
144	3	4				
145	3	2				
146	4	2				
147	4	3	5	5	6	3
148	5	1				
149	6	2	6	4	4	3
150	5	2	5	6	5	5

Table 3-5 BEACH UTILITY INDEX (con't.)

Station Number	Natural Protection Barriers	Shoreline Erosion/Accretion	Beach Width	Forebeach Grain Size	Backbeach Grain Size	Beach Access
151	5		5	5	4	6
152	3	4				
153	3	4				
154	4	4				
155	4	2				
156	4	2				
157	6	2	6		6	3
158	6					

AT STATION	E or A
1	0.6E
2	0.6E
3	0.8E
4	1.7E
5	0.0E

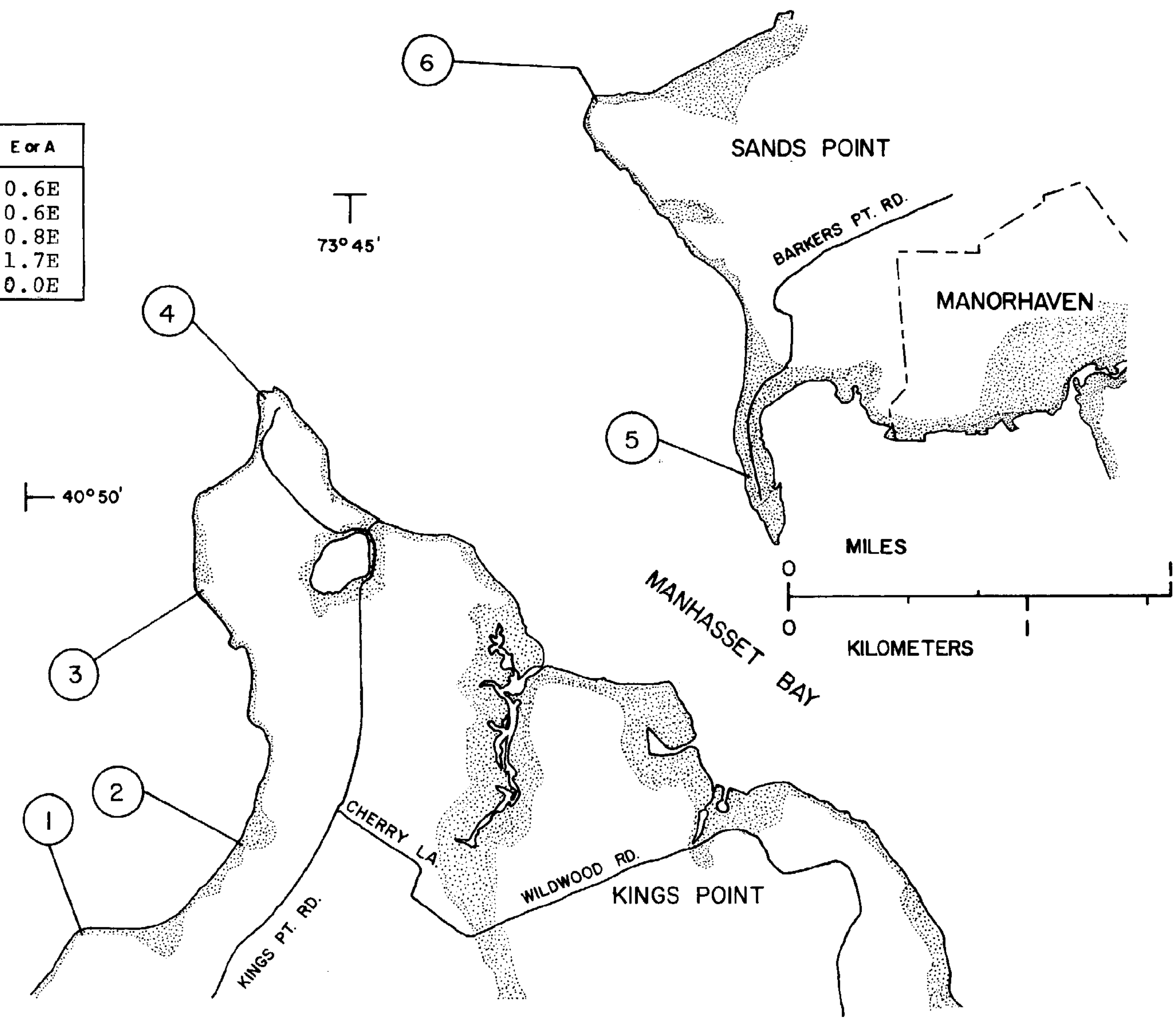


Fig. 3-1. Western North Hempstead Township.

AT STATION	E or A
6	0.6A
7	2.5A
8	0.6A
9	0.4E
10	1.5E
11	0.4E
12	0.3A
13	0.0E
14	0.6E
15	0.8E
16	1.3E

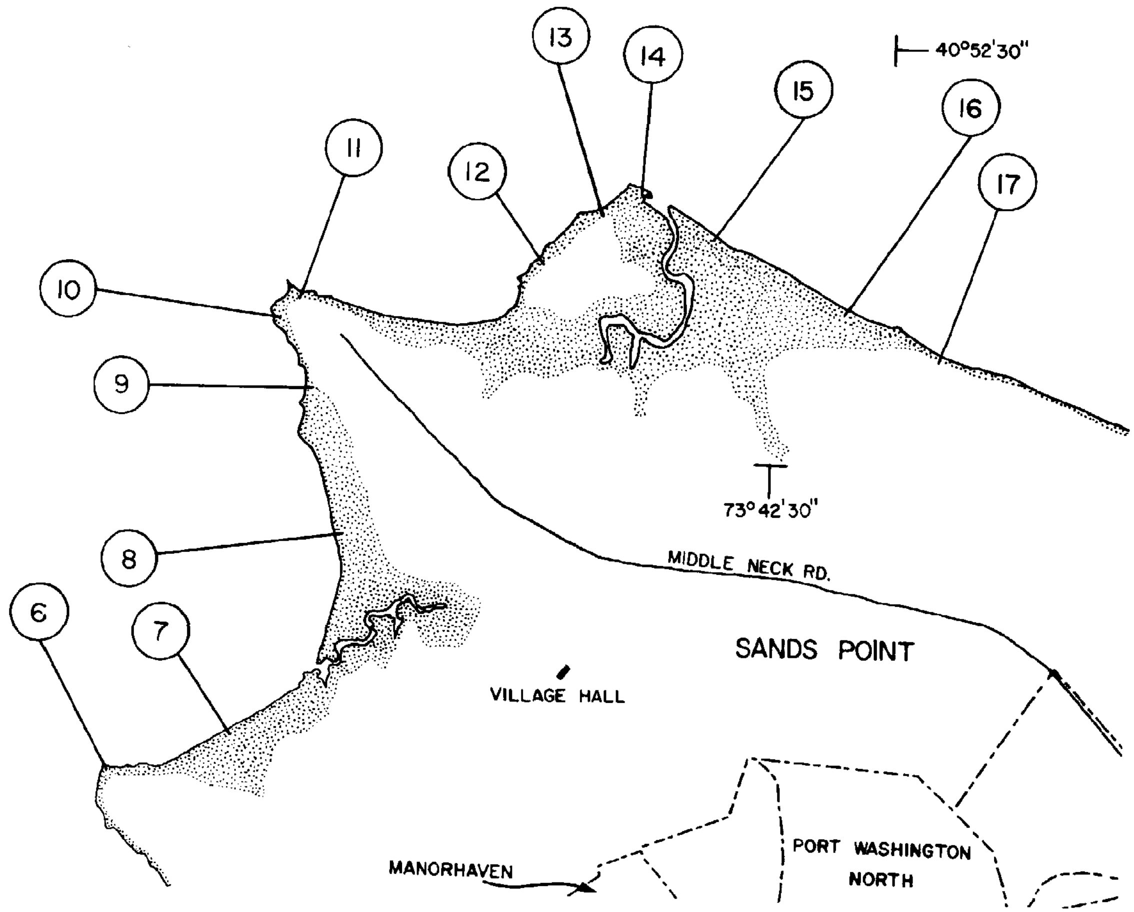
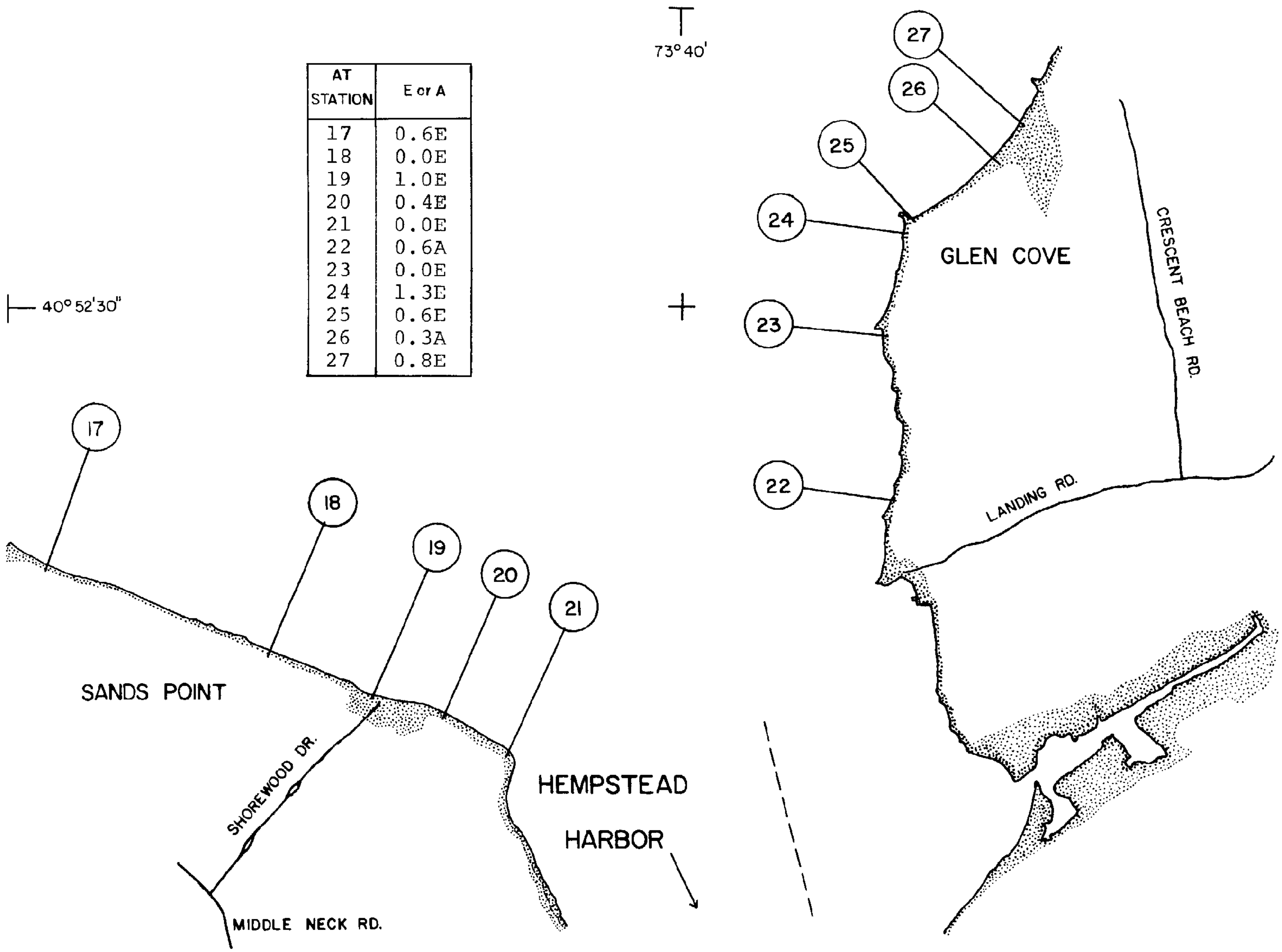


Fig. 3-2. Central North Hempstead Township.



AT STATION	E or A
17	0.6E
18	0.0E
19	1.0E
20	0.4E
21	0.0E
22	0.6A
23	0.0E
24	1.3E
25	0.6E
26	0.3A
27	0.8E

Fig. 3-3. Eastern North Hempstead and western Oyster Bay Townships.

AT STATION	E or A
28	0.6E
29	0.6A
30	0.0E
31	0.4E
32	0.6E
33	0.8E
34	0.0E
35	0.8A

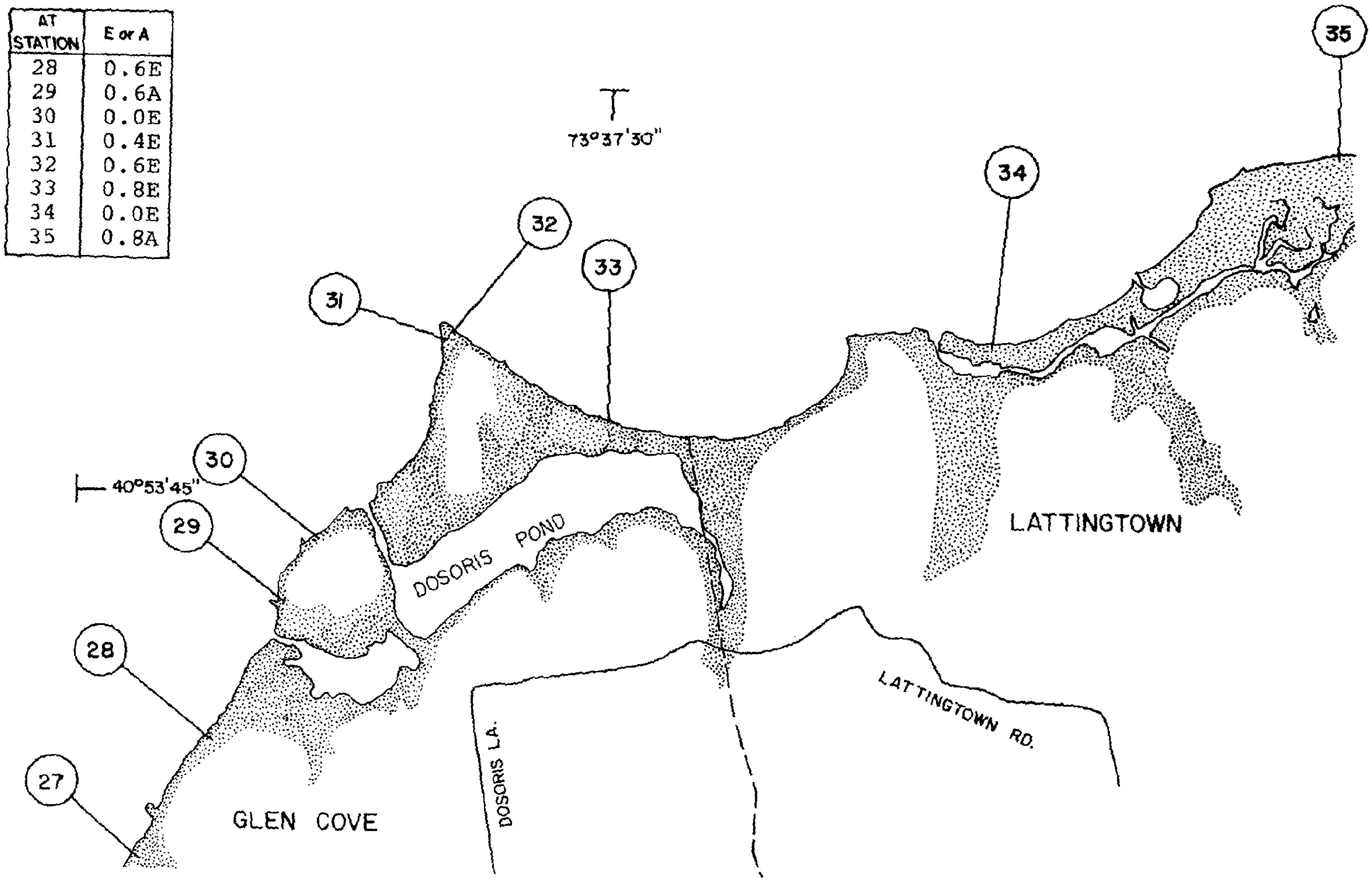


Fig. 3-4. Central Oyster Bay Township.

AT STATION	E or A
36	0.8A
37	2.9E
38	0.6E
39	*
40	*

*The beach in front of the Oak Neck-Centre Island Causeway received over 500,000 cu yds of sand fill in 1947. (See Addendum 1 for details.)

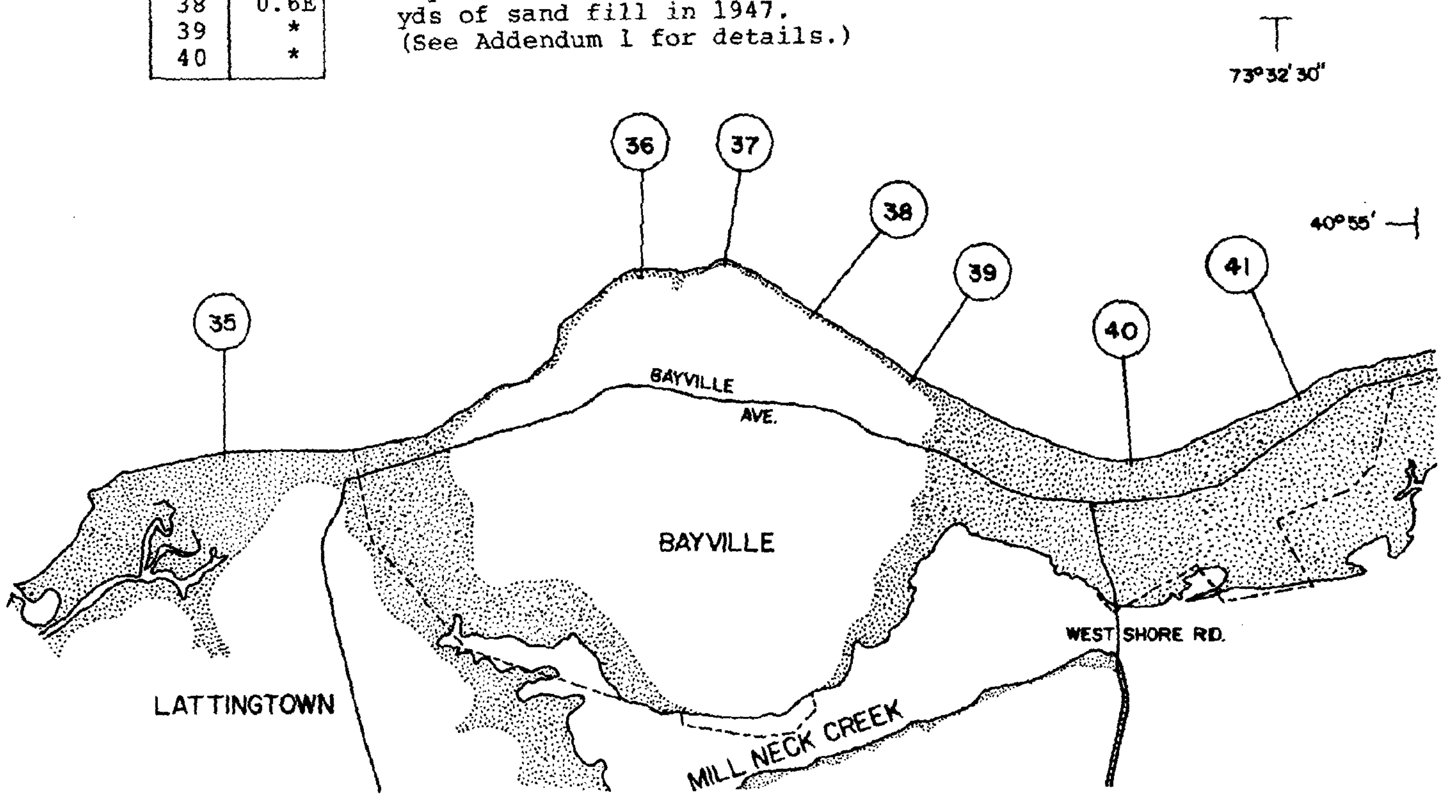
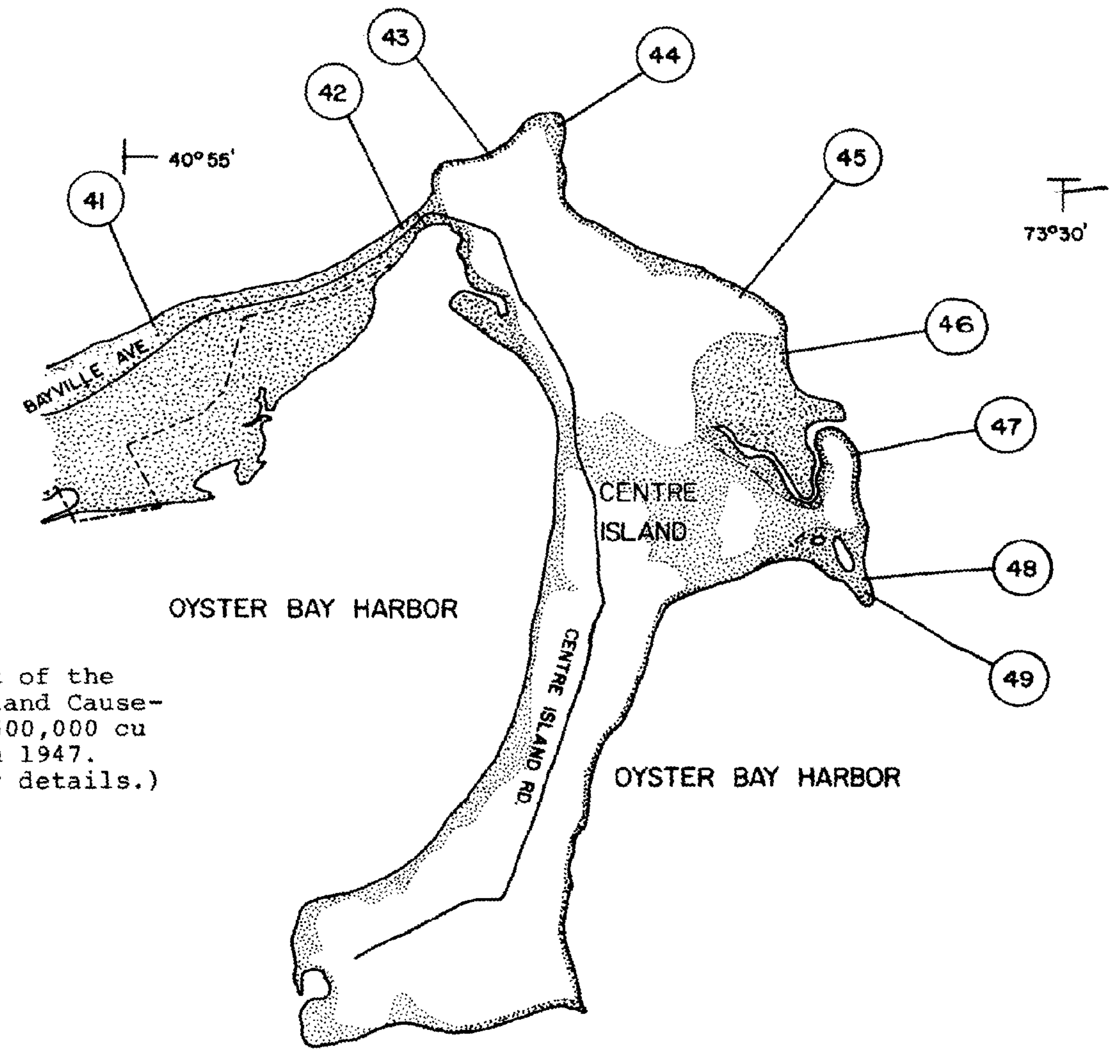


Fig. 3-5. Central Oyster Bay Township.

AT STATION	E or A
41	*
42	*
43	2.1E
44	2.1A
45	2.5E
46	0.2A
47	0.8E
48	1.3E
49	0.3E



*The beach in front of the Oak Neck-Centre Island Causeway received over 500,000 cu yds of sand fill in 1947. (See Addendum 1 for details.)

Fig. 3-6. Eastern Oyster Bay Township.

BETWEEN STATIONS	AVERAGE E or A
50-51	0.4A
51-52	1.0A
52-54	0.6E
54-55	1.6E

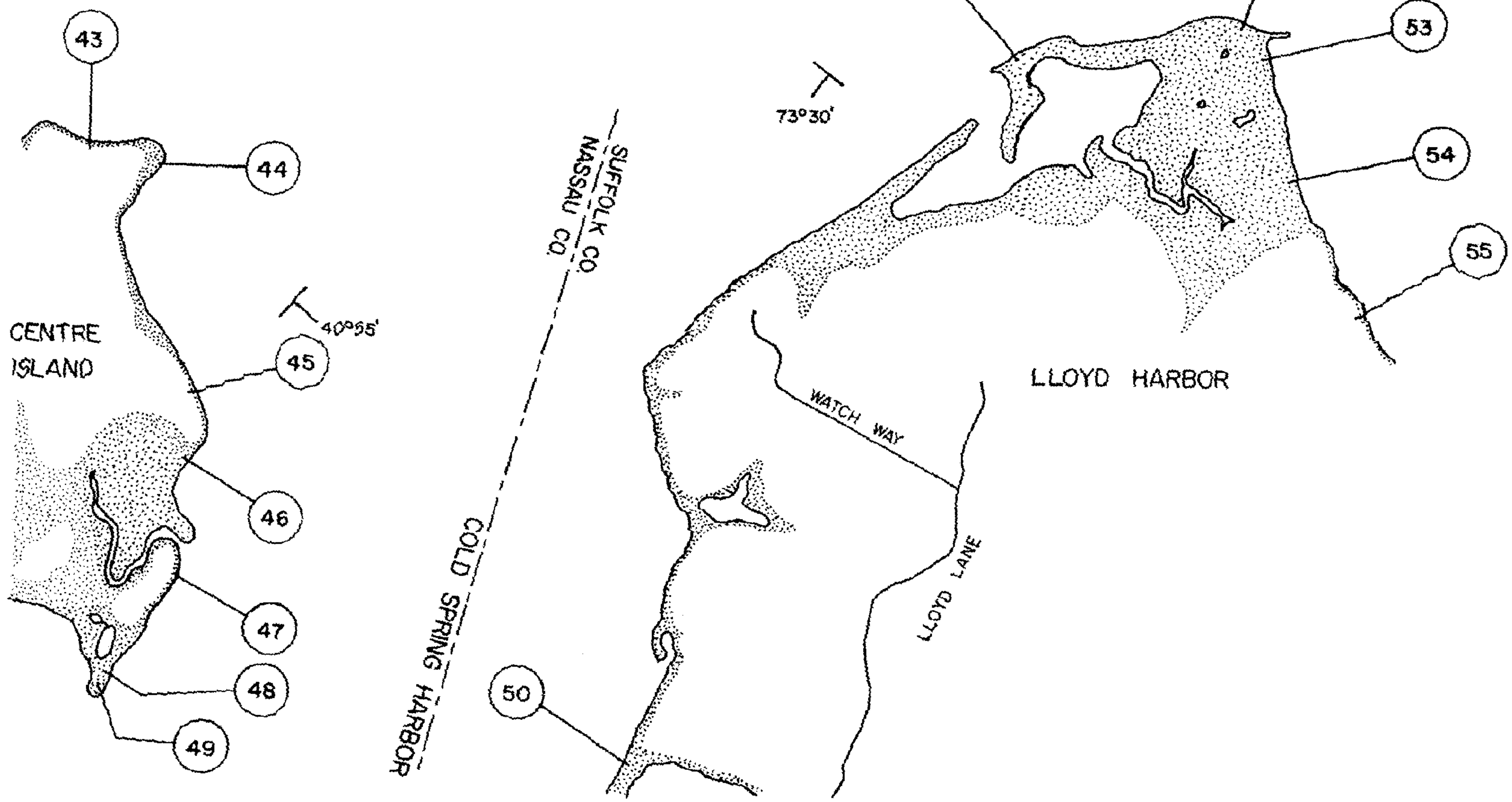
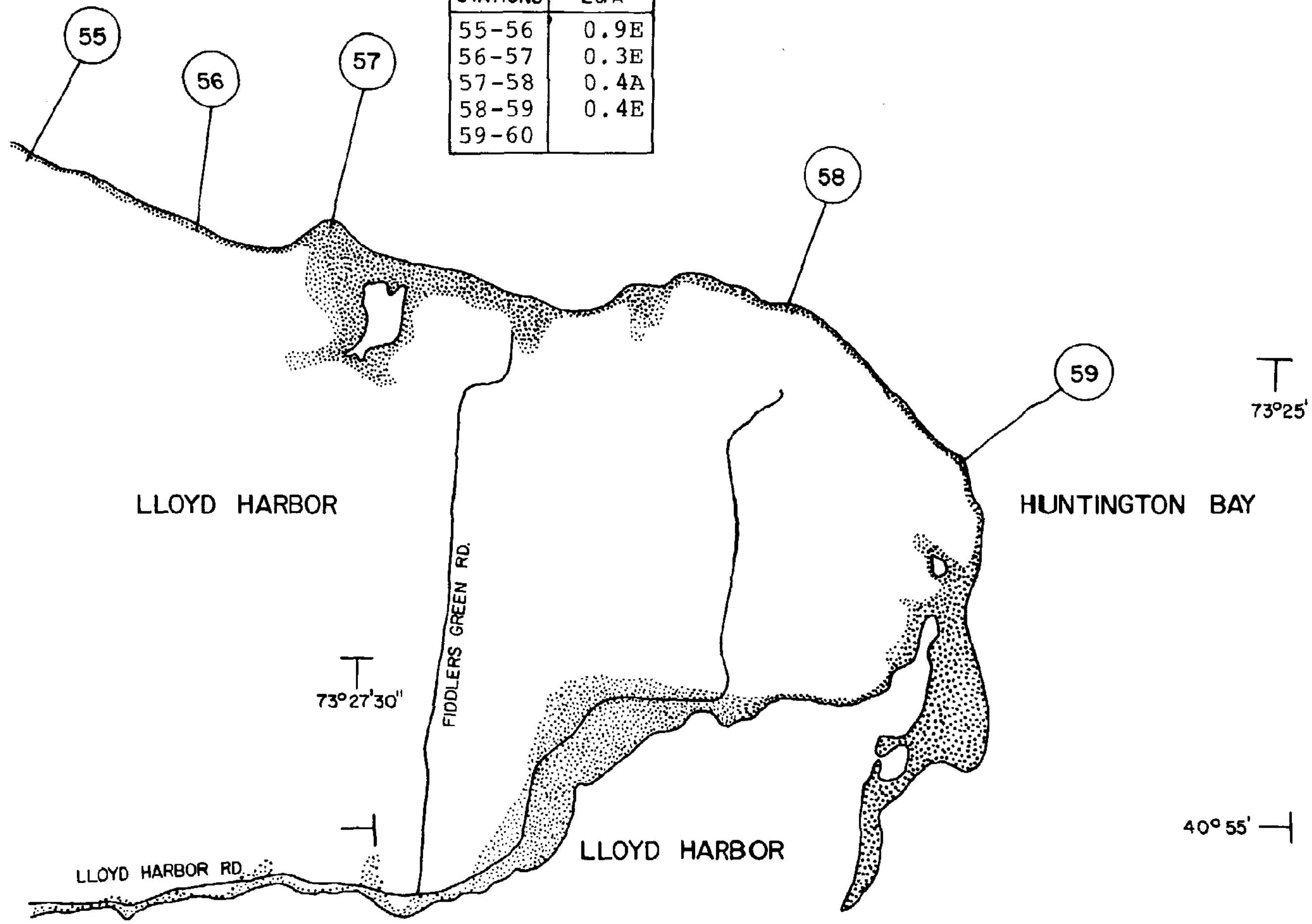


Fig. 3-7. Eastern Huntington Township.



BETWEEN STATIONS	AVERAGE E or A
55-56	0.9E
56-57	0.3E
57-58	0.4A
58-59	0.4E
59-60	

Fig. 3-8. Eastern Huntington Township.

BETWEEN STATIONS	AVERAGE E or A
60-61	0.8E
61-62	0.6E
62-63	0.8E
63-64	0.8E
64-65	3.0E
65-66	1.1E
66-67	*0.2E

*Asharoken Beach received over 840,000 cu yds of sand fill between 1960 and 1964. Erosion data are from 1886 to 1931.

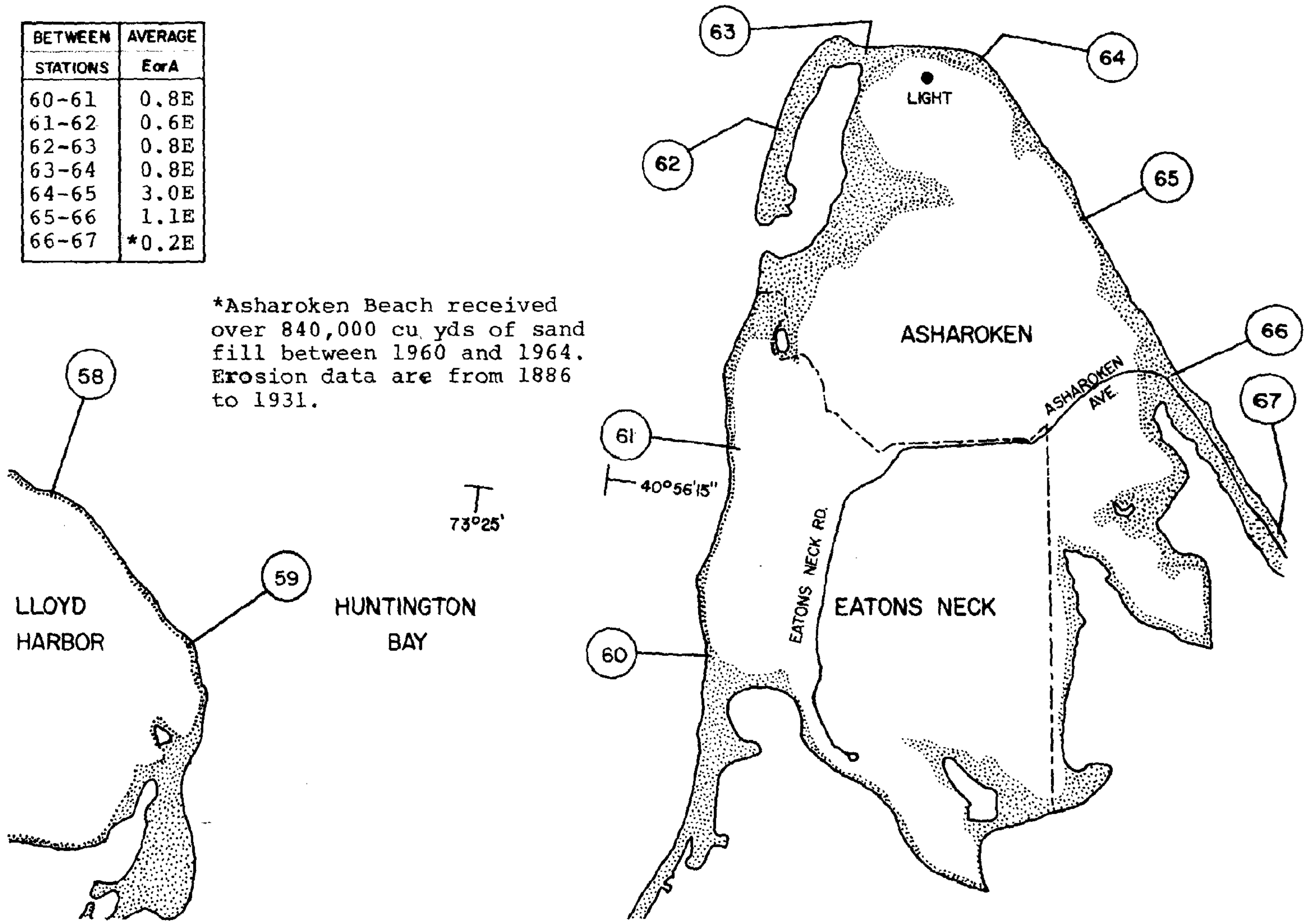


Fig. 3-9. Central Huntington Township.

BETWEEN STATIONS	AVERAGE E or A
67-68	*0.2E
68-69	*0.8E
69-70	*1.4E
70-71	1.0A

*Asharoken Beach received over 840,000 cu yds of sand fill between 1960 and 1964. Erosion data between Stations 67-68 are from 1886-1931. Erosion data between Stations 68-70 are from 1886-1916.

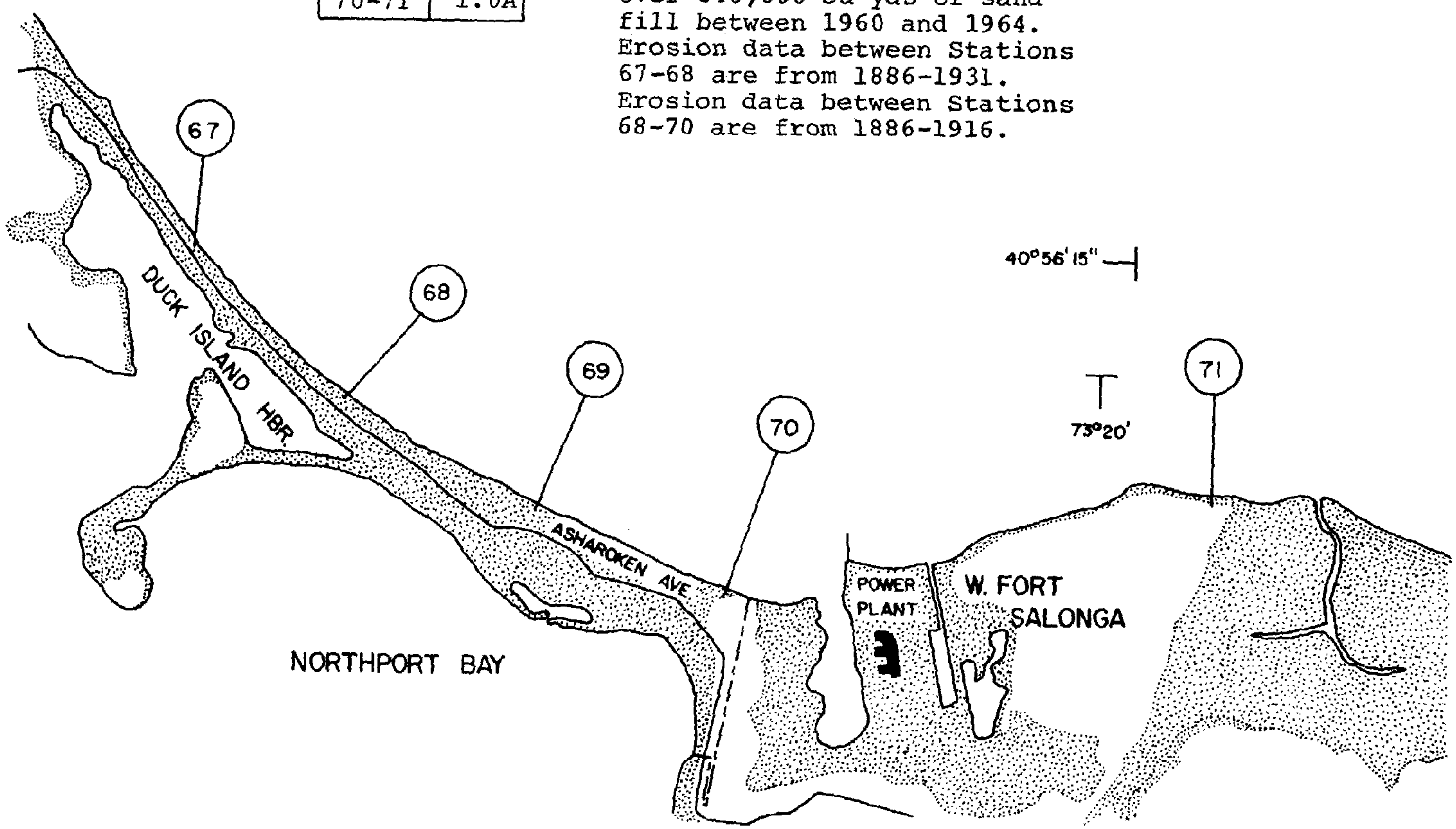


Fig. 3-10. Central Huntington Township.

BETWEEN STATIONS	AVERAGE E or A
71-72	0.2E
72-73	1.1E
73-74	1.9E

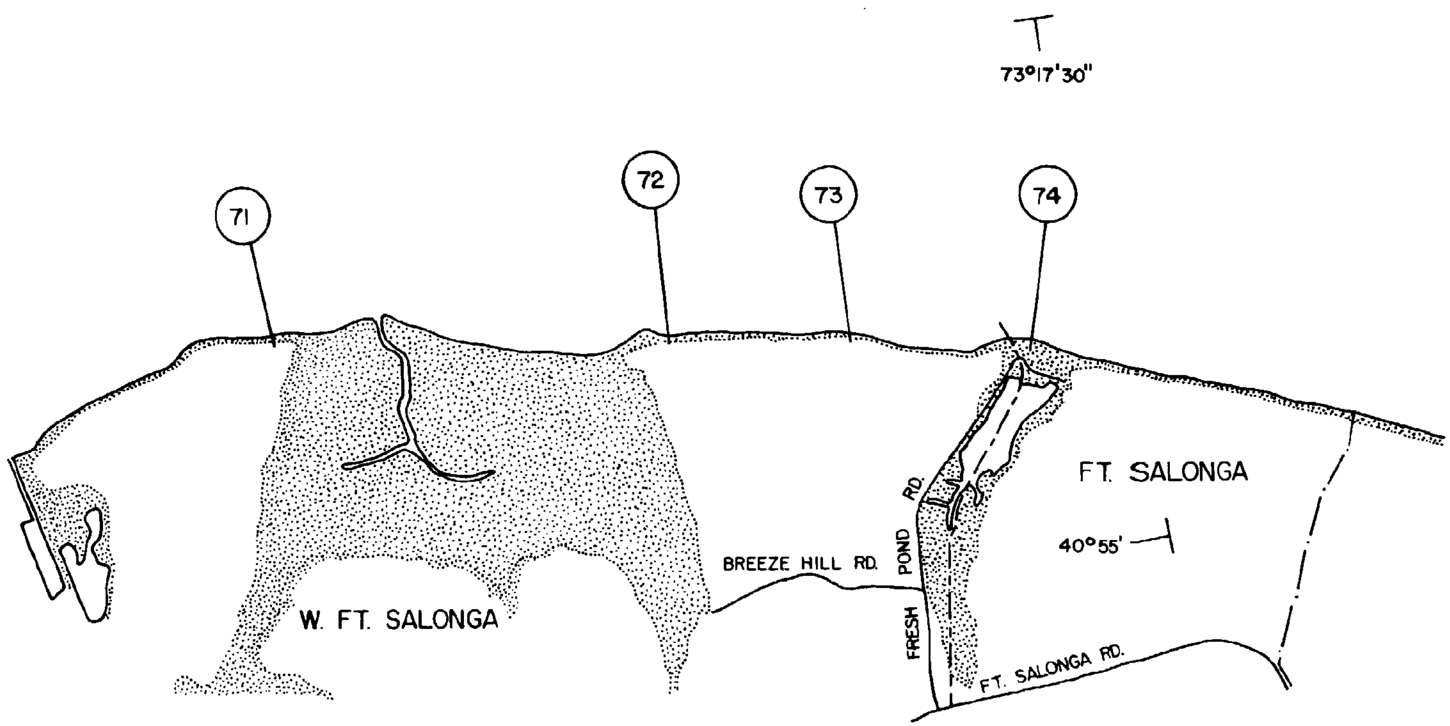


Fig. 3-11. Eastern Huntington Township.

BETWEEN STATIONS	AVERAGE E or A
74-75	1.38
75-76	*2.5E
76-77	*2.6E
77-78	*3.3E

*Sunken Meadow State Park received over 57,000 cu yds of sand fill in 1957. Erosion data between Stations 75-78 are from 1886 to 1916.

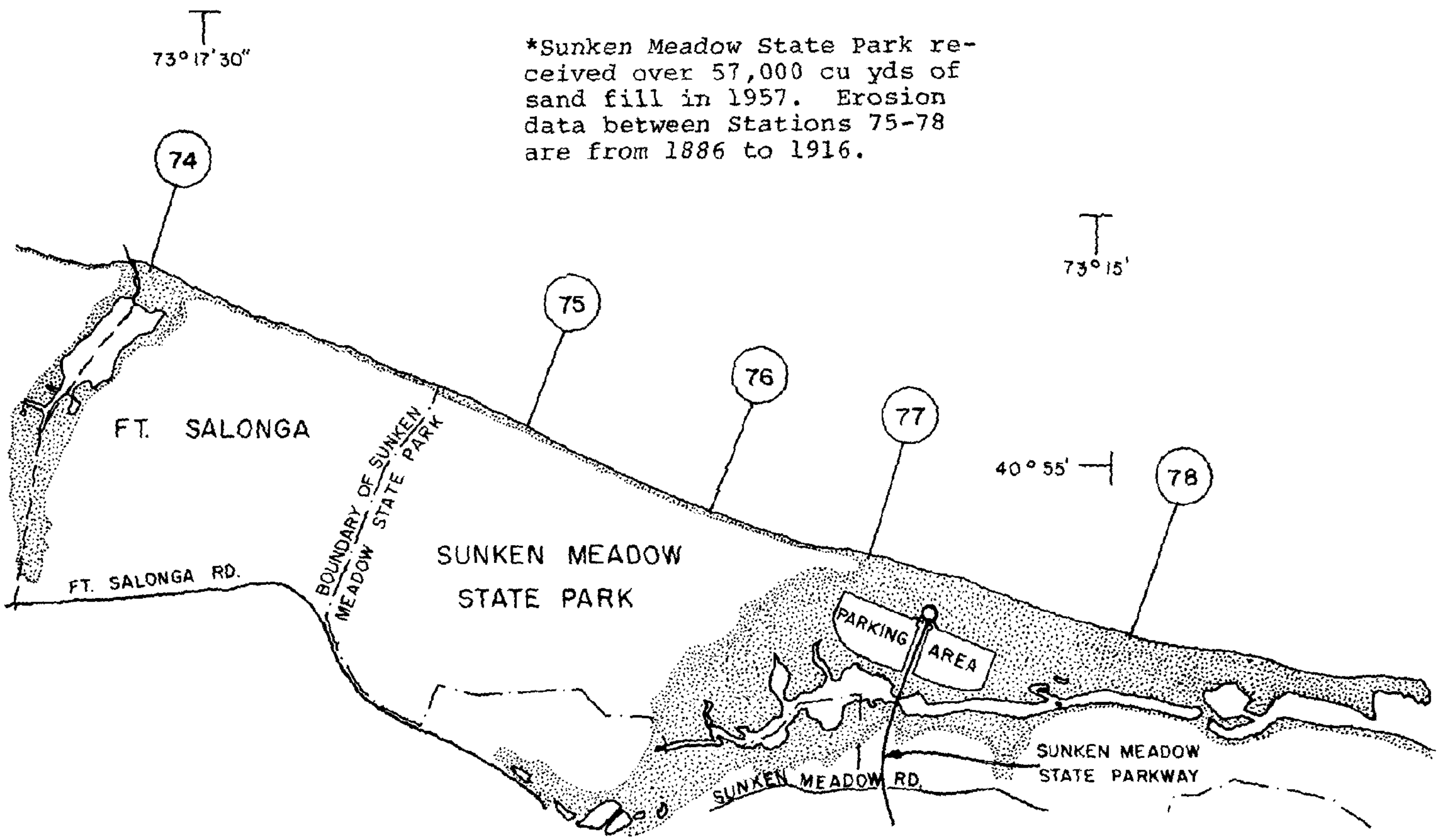


Fig. 3-12. Western Smithtown Township.

BETWEEN STATIONS	AVERAGE E or A
78-79	*1.7A
79-80	*0.4E
80-81	0.0E

*The Nissequogue River was dredged between 1958 and 1962, with spoil placed on beaches at the mouth of the Nissequogue. Erosion data between Stations 78 and 79 are from 1886 to 1916, and between Stations 79 and 80 are from 1836 to 1886.

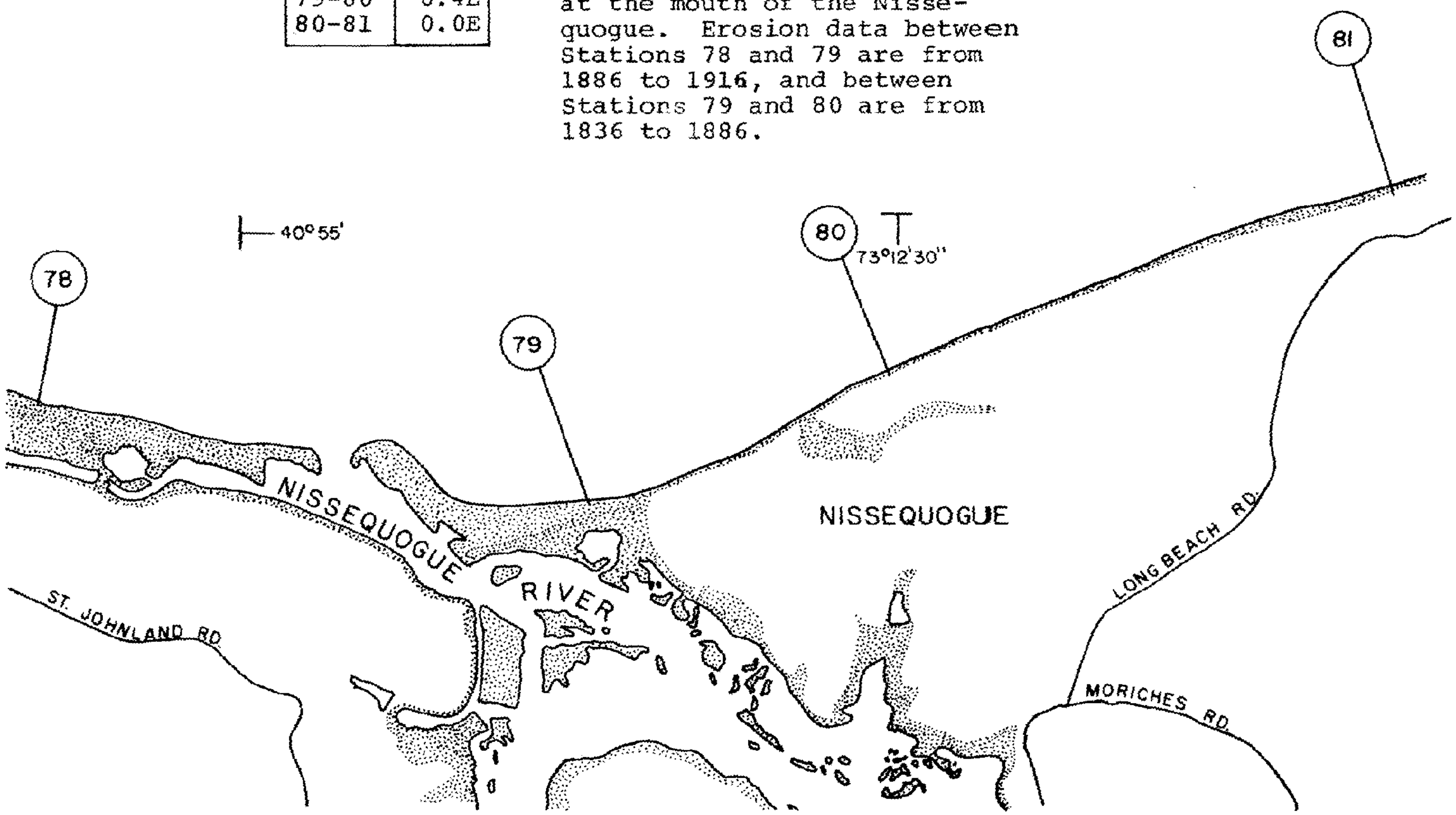


Fig. 3-13. Central Smithtown Township.

BETWEEN STATIONS	AVERAGE E or A
81-82	0.6A
82-83	0.4A
83-84	0.7E
84-85	1.6E

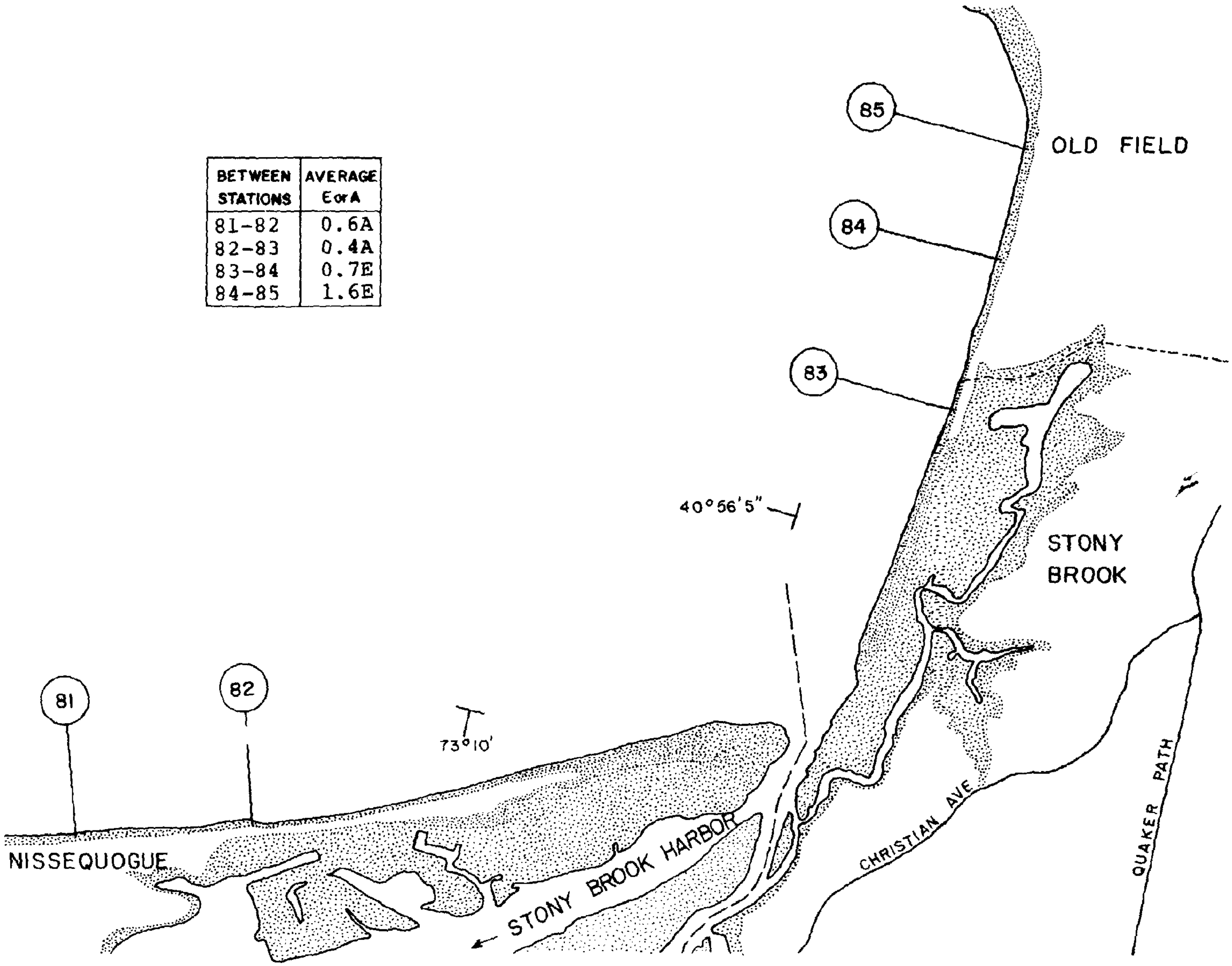


Fig. 3-14. Eastern Smithtown and western Brookhaven Townships.

BETWEEN STATIONS	AVERAGE E or A
85-86	1.6E
86-87	0.8E
87-88	0.7E
88-89	0.8E
89-90	1.0E
90-91	1.7E

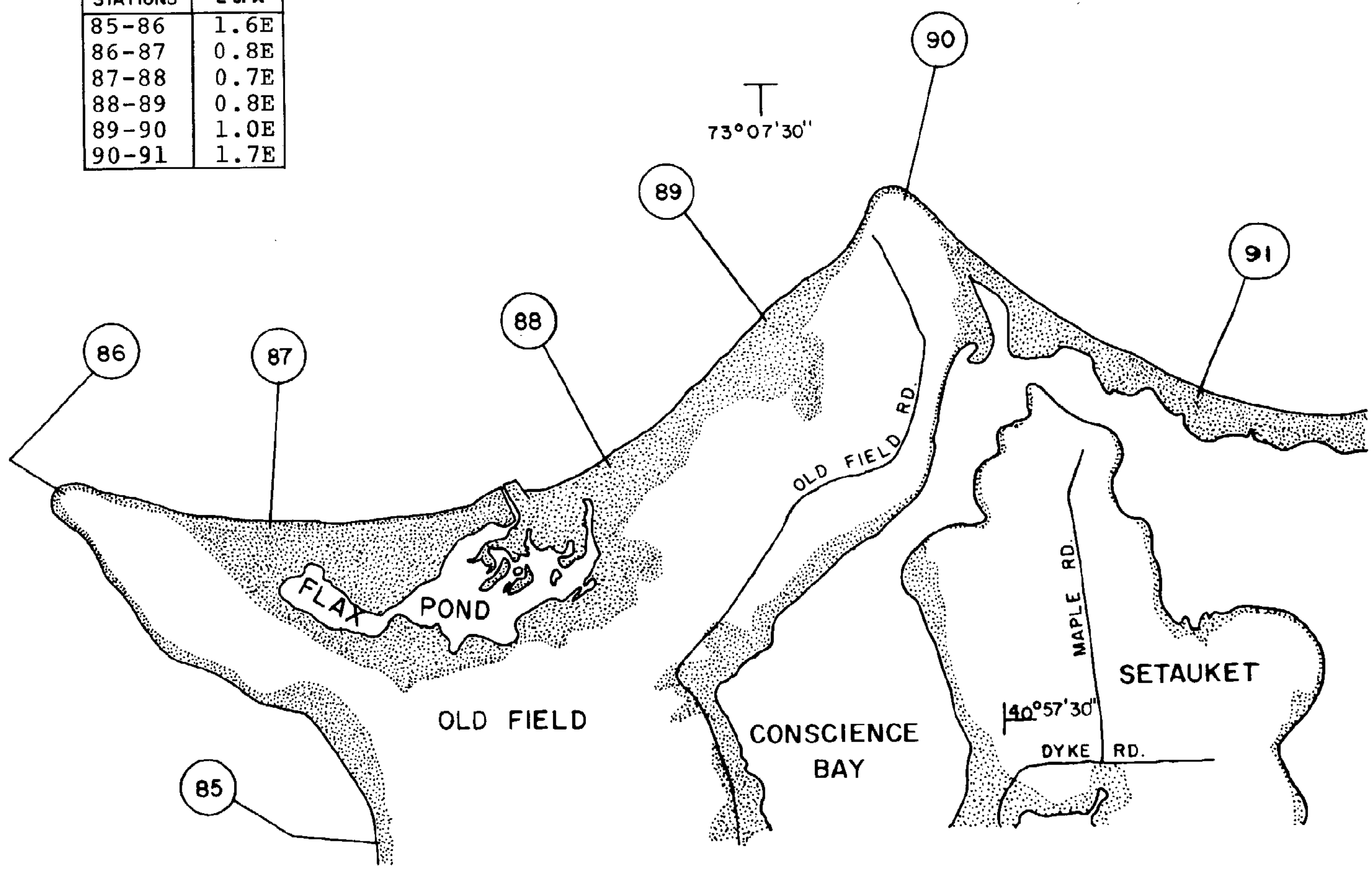


Fig. 3-15. Western Brookhaven Township.

BETWEEN STATIONS	AVERAGE E or A
91-92	*
92-93	0.2A
93-94	0.3A
94-95	0.7A
95-96	0.8E

*Port Jefferson Harbor has been dredged since 1891 with some spoil placed on the beaches on either side of the entrance. Erosion data are not available.

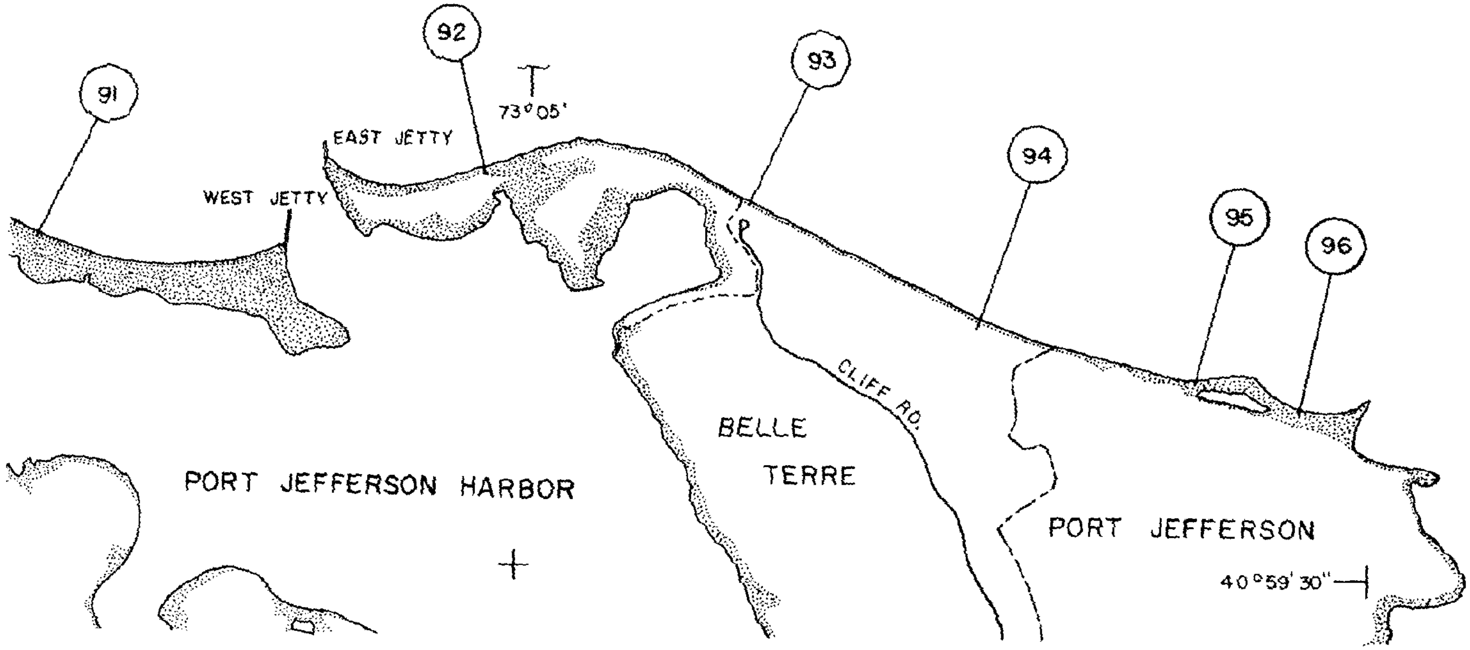


Fig. 3-16. Western Brookhaven Township.

BETWEEN STATIONS	AVERAGE E or A
96-97	*
97-98	*1.0E
98-99	0.2E
99-100	0.3A
100-101	1.5E

*Mt. Sinai Harbor was dredged from 1951 to 1967, with dredge spoil placed on the beaches at the entrance of the Harbor. Erosion data between Stations 96-97 are not available, and between Stations 97 and 98 are from 1886 to 1931.

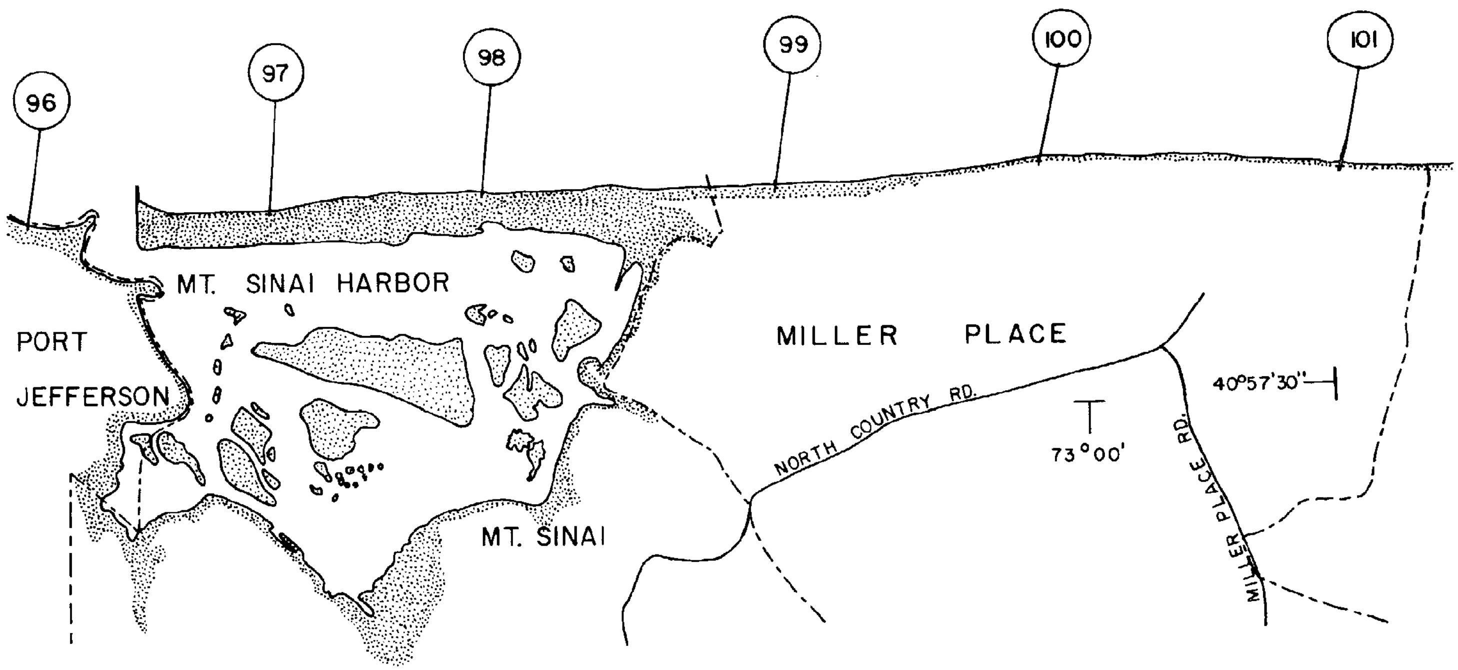


Fig. 3-17, Central Brookhaven Township.

BETWEEN STATIONS	AVERAGE E or A
101-102	1.4E
102-103	1.9E
103-104	1.8E

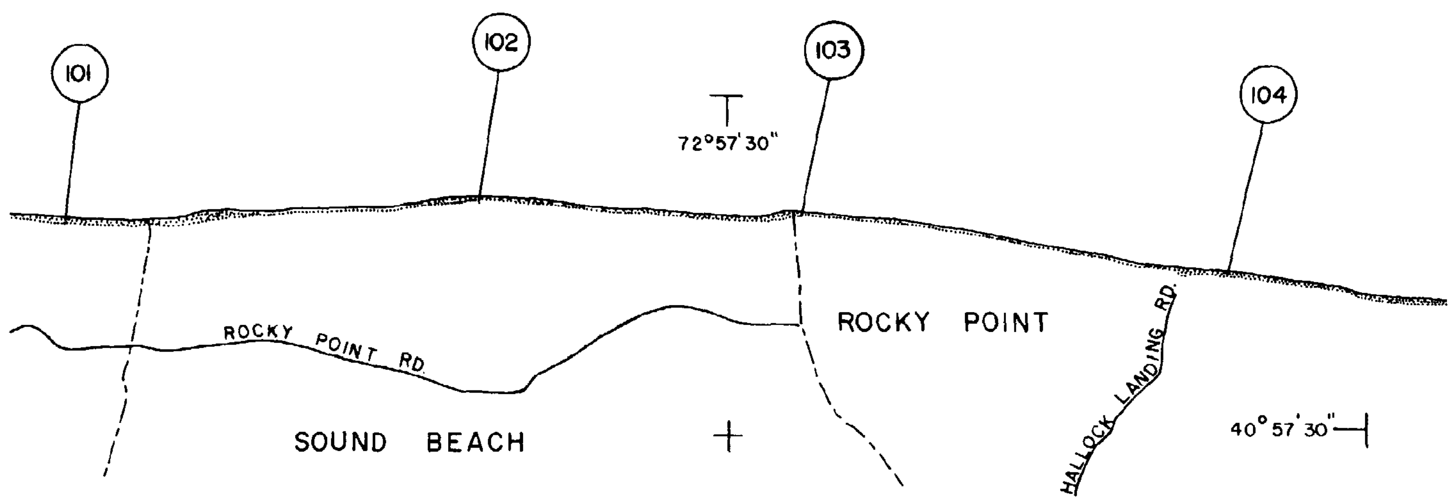


Fig. 3-18. Central Brookhaven Township.

BETWEEN STATIONS	AVERAGE E or A
104-105	1.4E
105-106	1.4E
106-107	0.8E

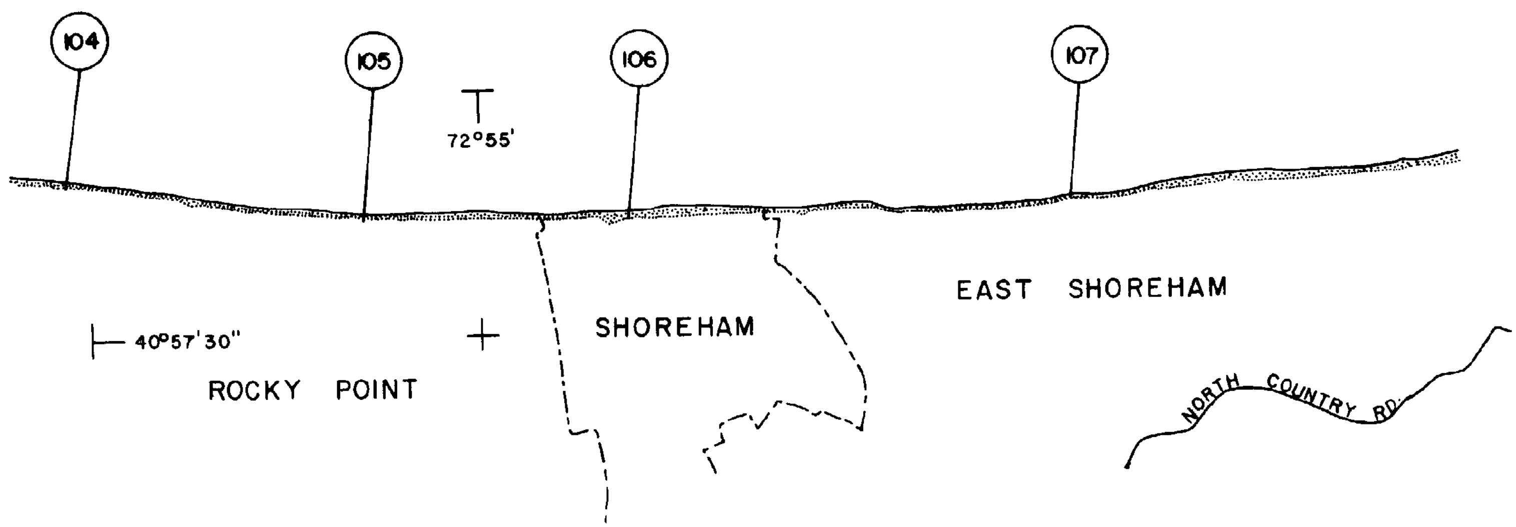


Fig. 3-19. Eastern Brookhaven Township.

BETWEEN STATIONS	AVERAGE E or A
107-108	0.1E
108-109	1.3E
109-110	0.8E
110-111	1.4E

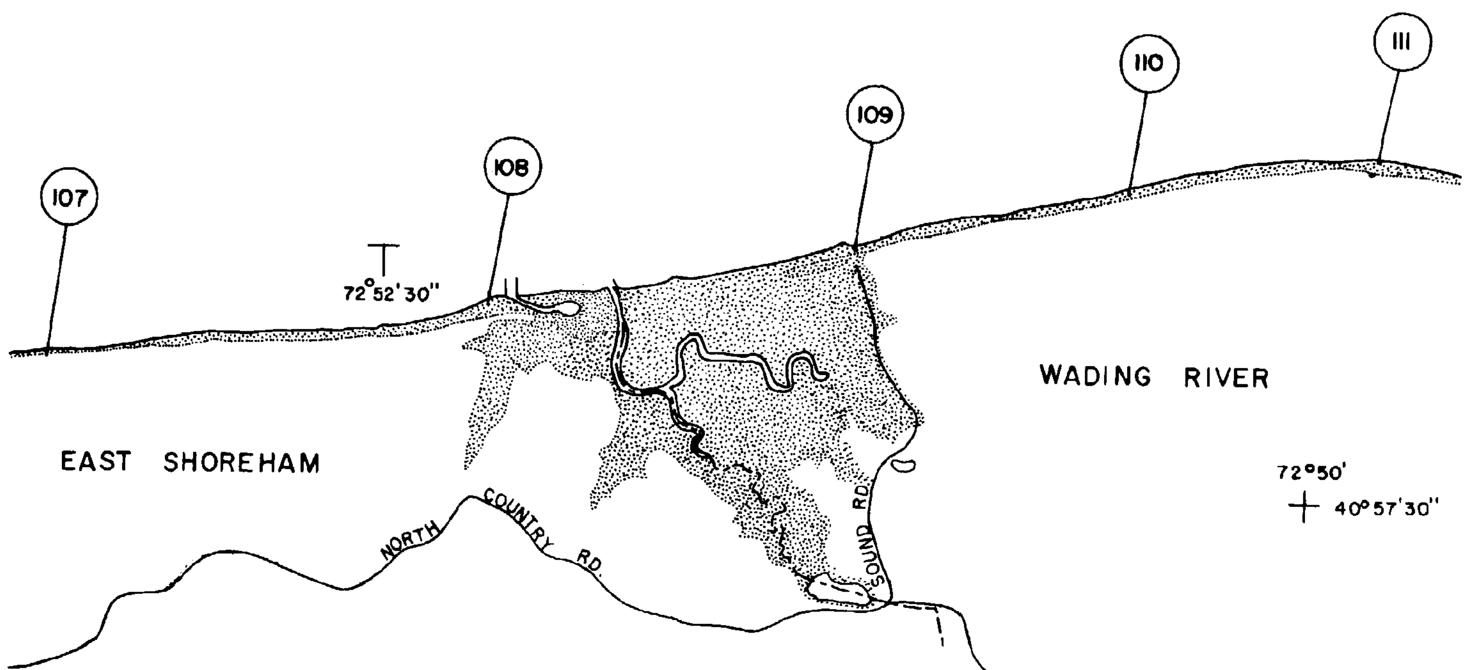


Fig. 3-20. Eastern Brookhaven and western Riverhead Townships.

BETWEEN STATIONS	AVERAGE E or A
111-112	1.0E
112-113	0.5E
113-114	1.1E
114-115	1.8E

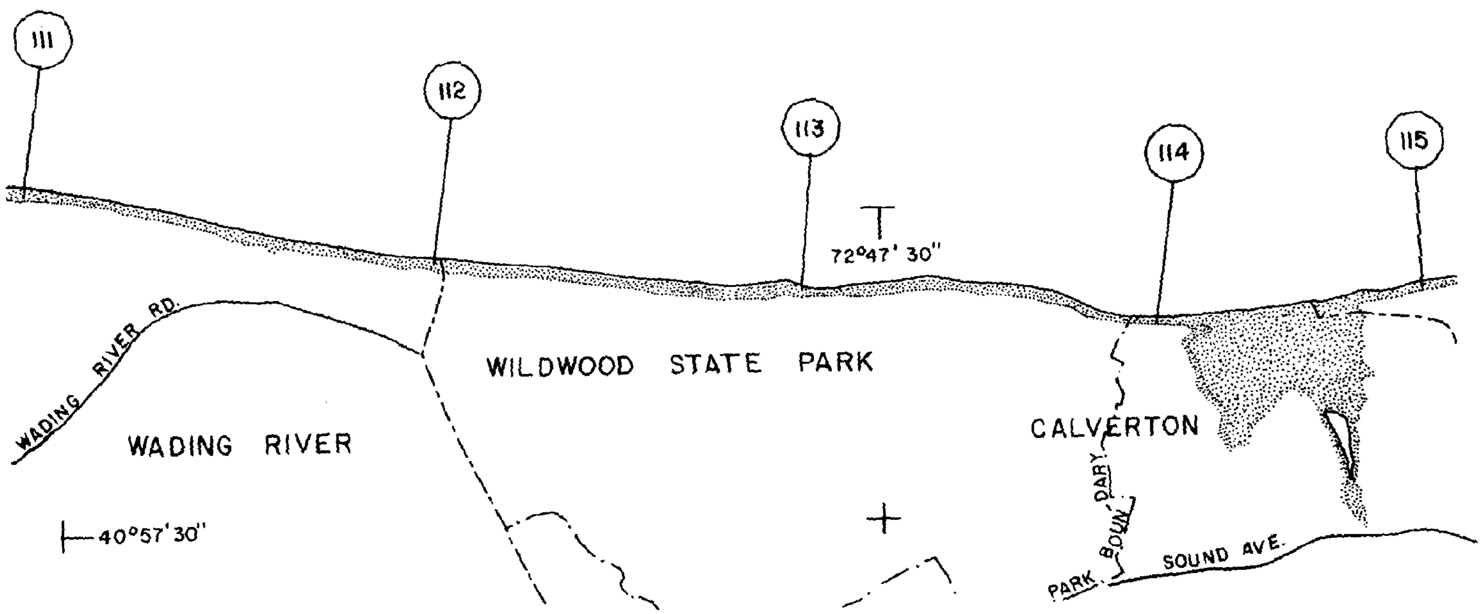


Fig. 3-21. Western Riverhead Township.

BETWEEN STATIONS	AVERAGE E or A
115-116	2.1E
116-117	2.2E
117-118	2.5E

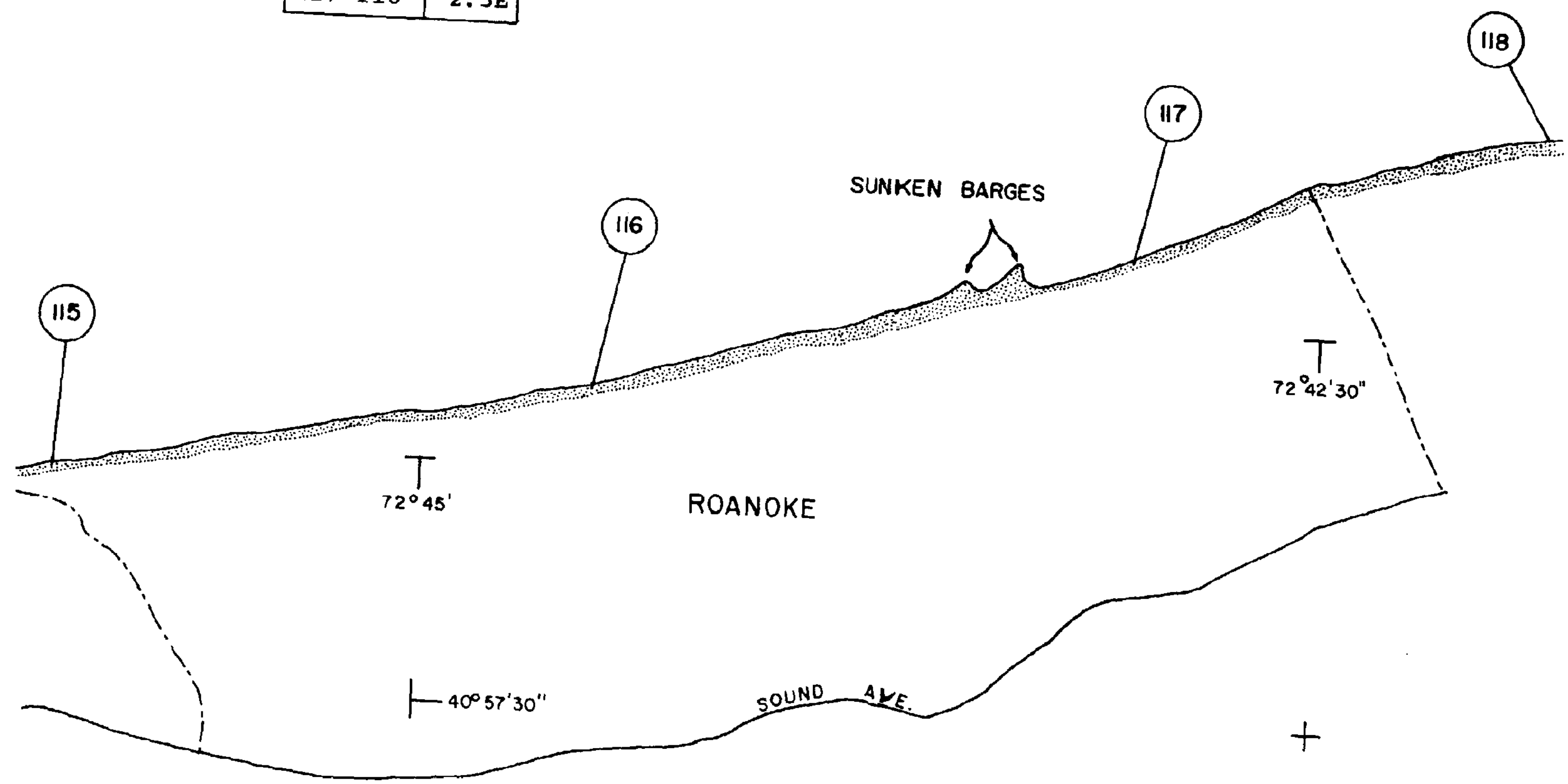


Fig. 3-22. Central Riverhead Township.

BETWEEN STATIONS	AVERAGE E or A
118-119	2.7E
119-120	1.6E
120-121	1.8E
121-122	1.1E
122-123	3.7E

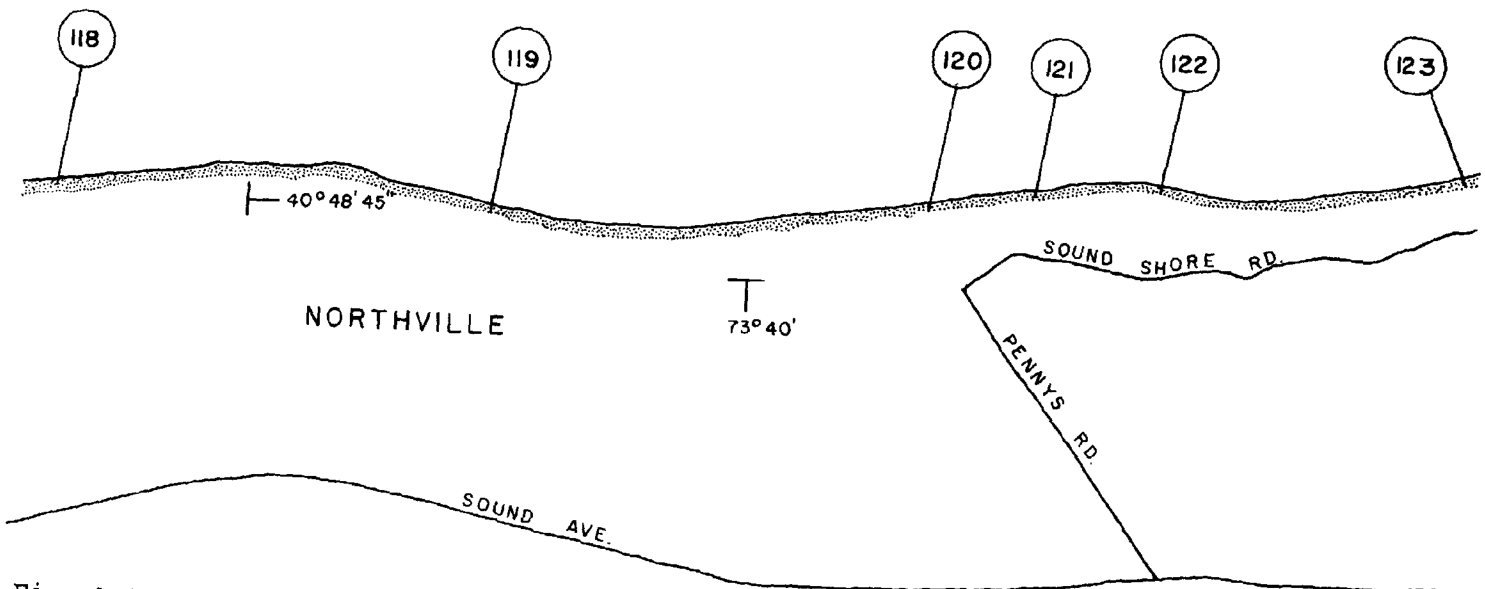


Fig. 3-23. Eastern Riverhead Township.

BETWEEN STATIONS	AVERAGE E or A
123-124	1.0E
124-125	1.0E
125-126	1.0E
126-127	1.4E

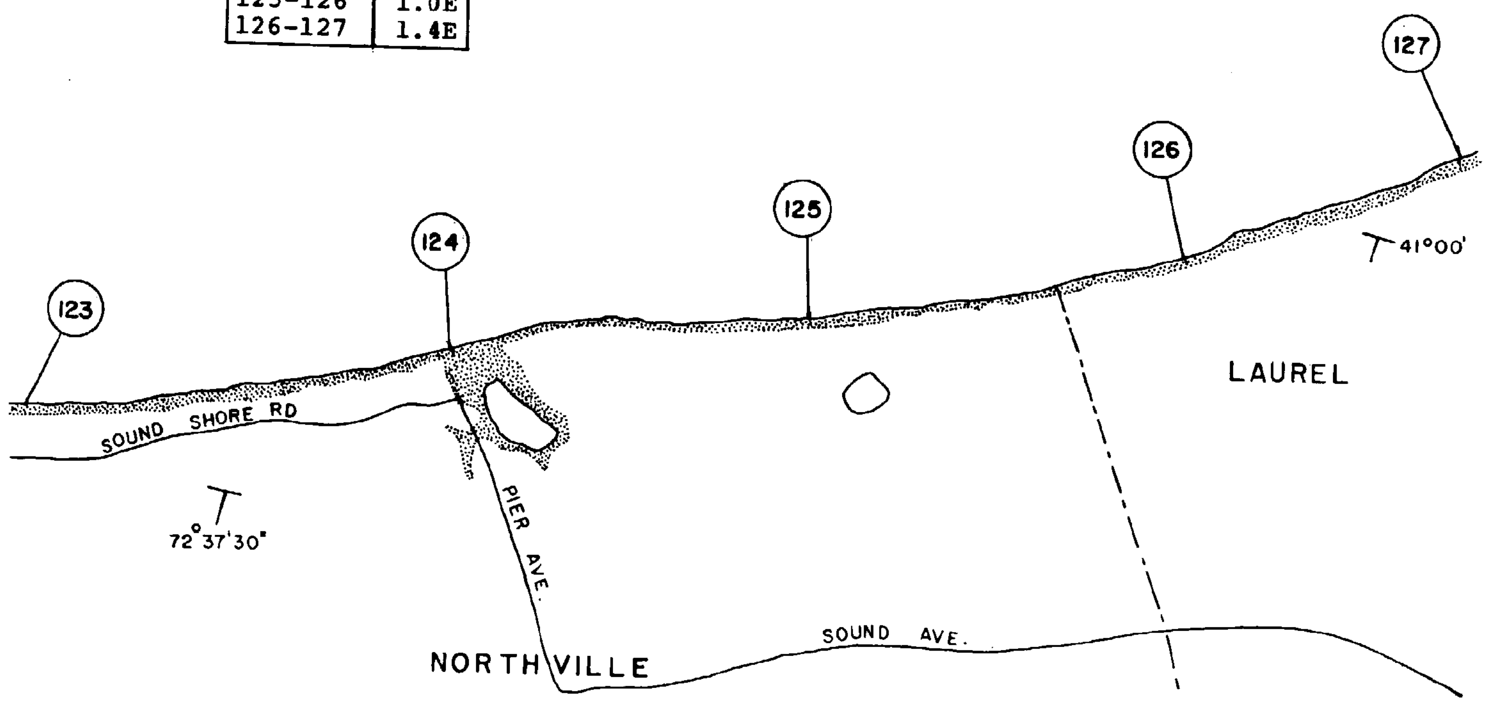
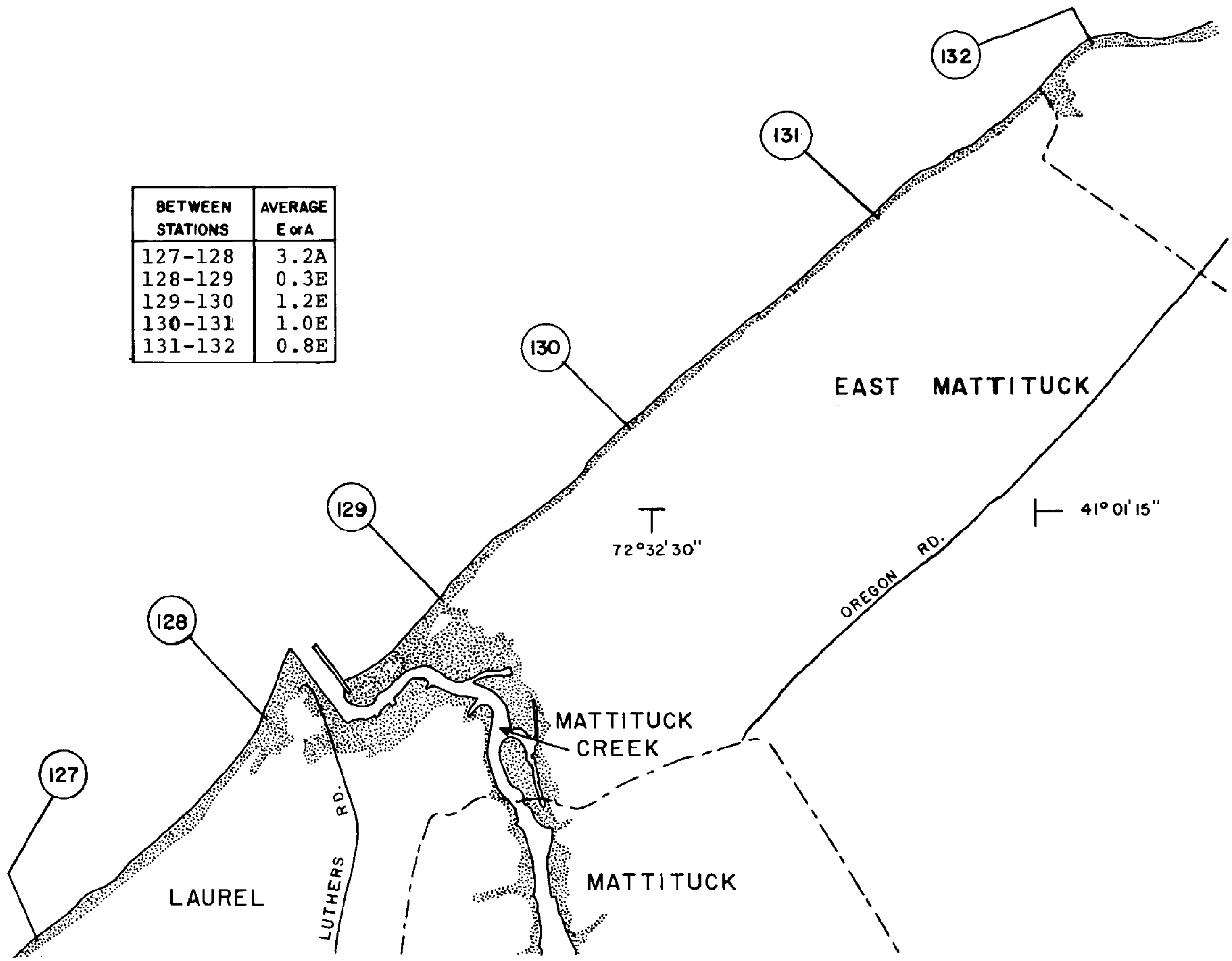


Fig. 3-24. Eastern Riverhead and western Southold Townships.



BETWEEN STATIONS	AVERAGE E or A
127-128	3.2A
128-129	0.3E
129-130	1.2E
130-131	1.0E
131-132	0.8E

Fig. 3-25. Western Southold Township.

BETWEEN STATIONS	AVERAGE E or A
132-133	0.4E
133-134	0.8E
134-135	2.0E
135-136	1.6E
136-137	1.9E

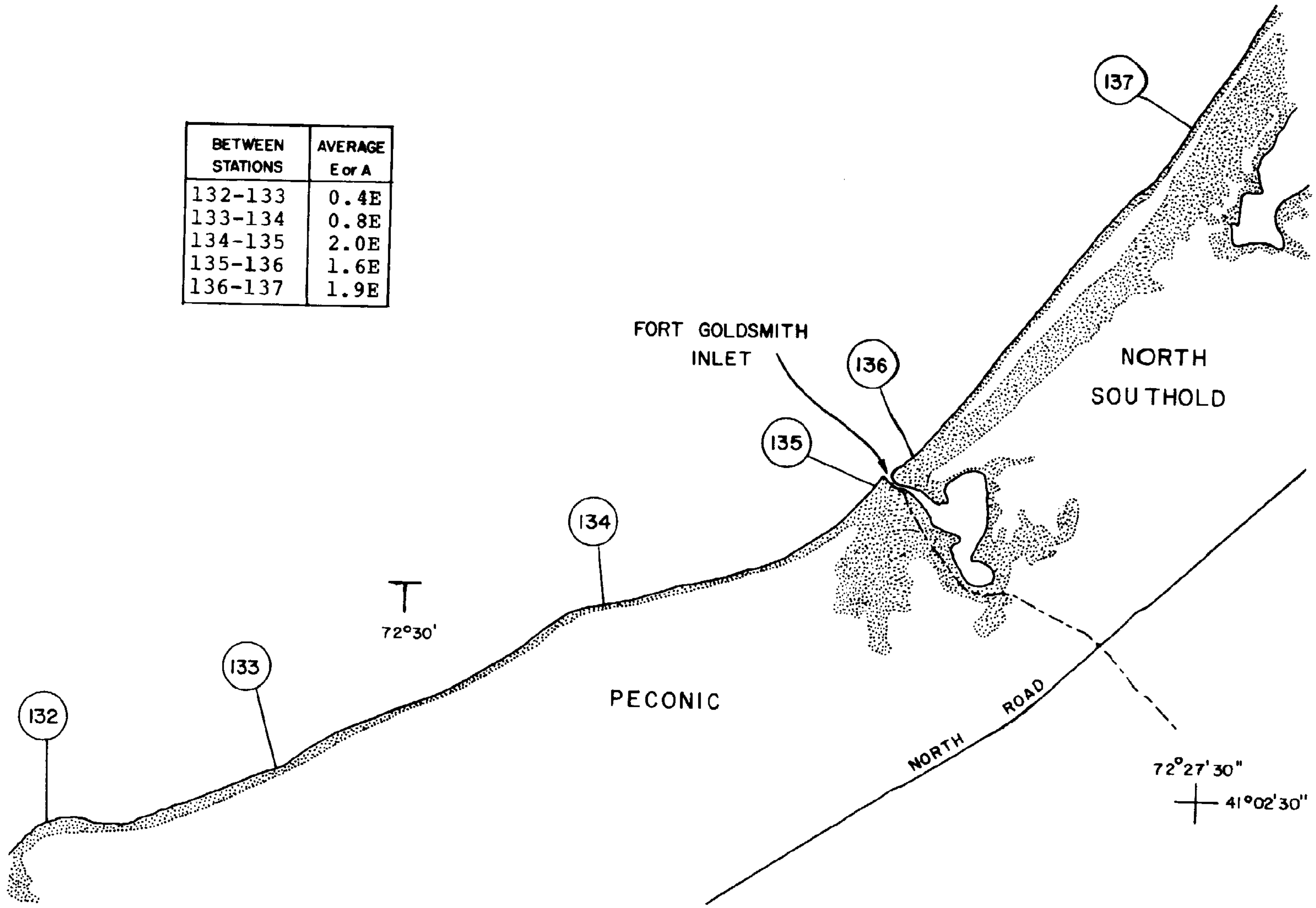


Fig. 3-26. Central Southold Township.

BETWEEN STATIONS	AVERAGE E or A
137-138	1.9E
138-139	0.7E
139-140	0.4E
140-141	0.8A

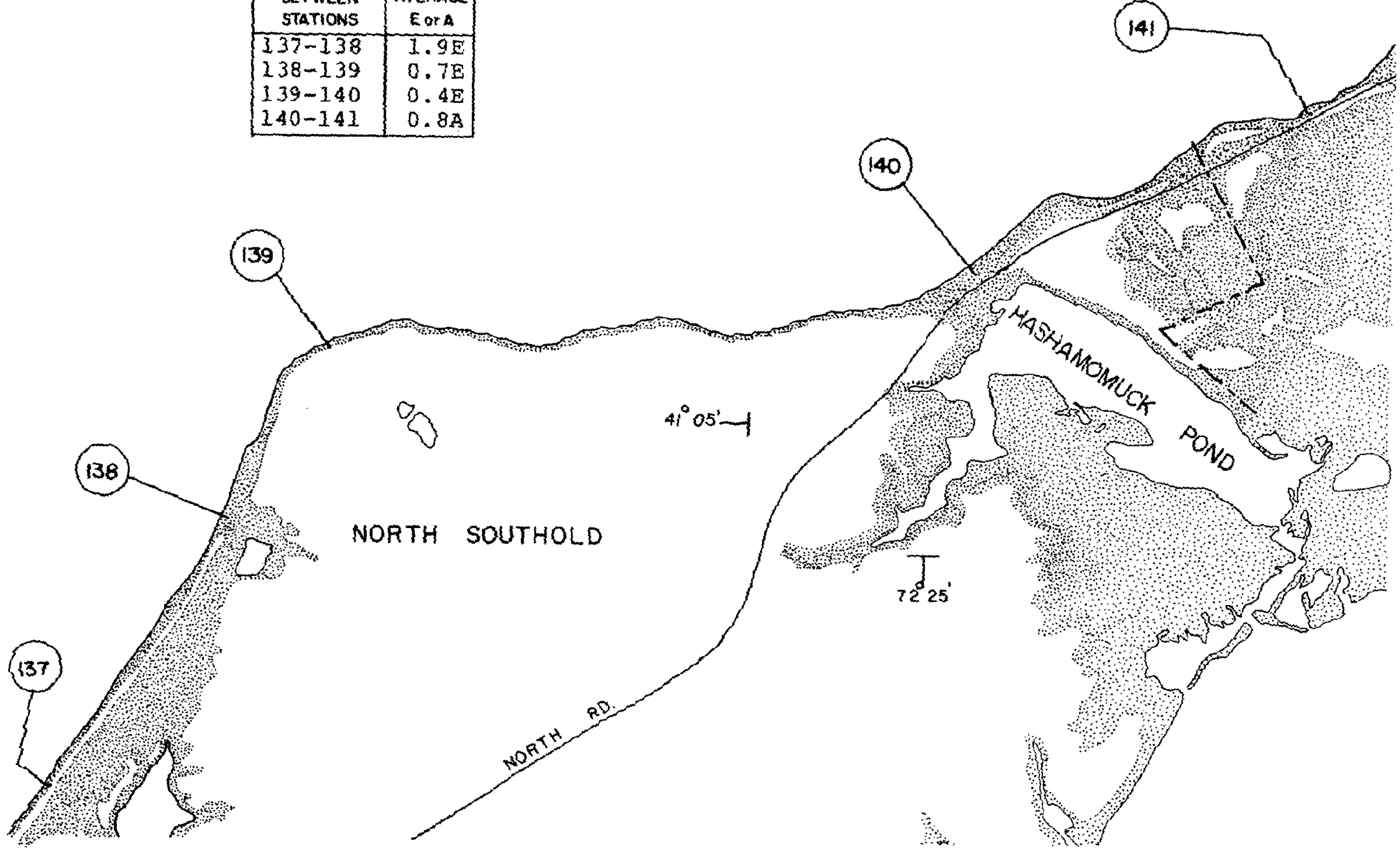


Fig. 3-27. Central Southold Township.

BETWEEN STATIONS	AVERAGE E or A
141-142	0.6A
142-143	1.8A
143-144	0.4E
144-145	0.3E

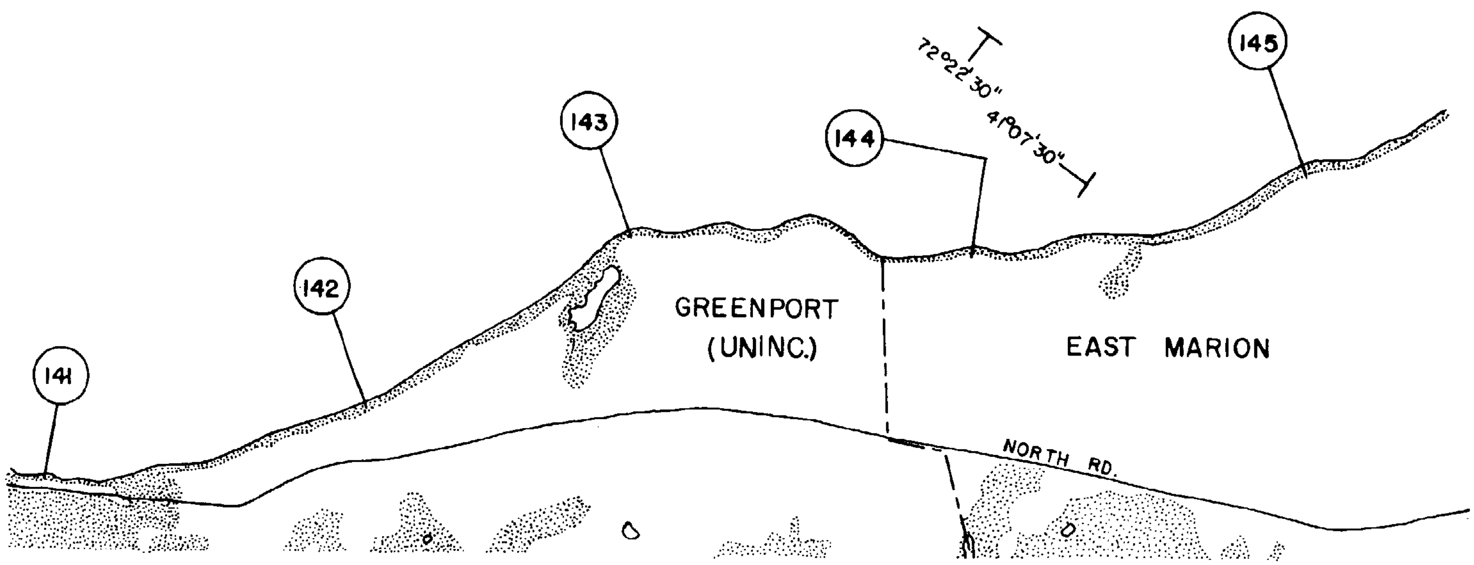


Fig. 3-28. Central Southold Township.

BETWEEN STATIONS	AVERAGE E or A
145-146	0.5E
146-147	0.6A
147-148	0.9E
148-149	0.0E
149-150	0.4A
150-151	0.4E
151-152	0.3E

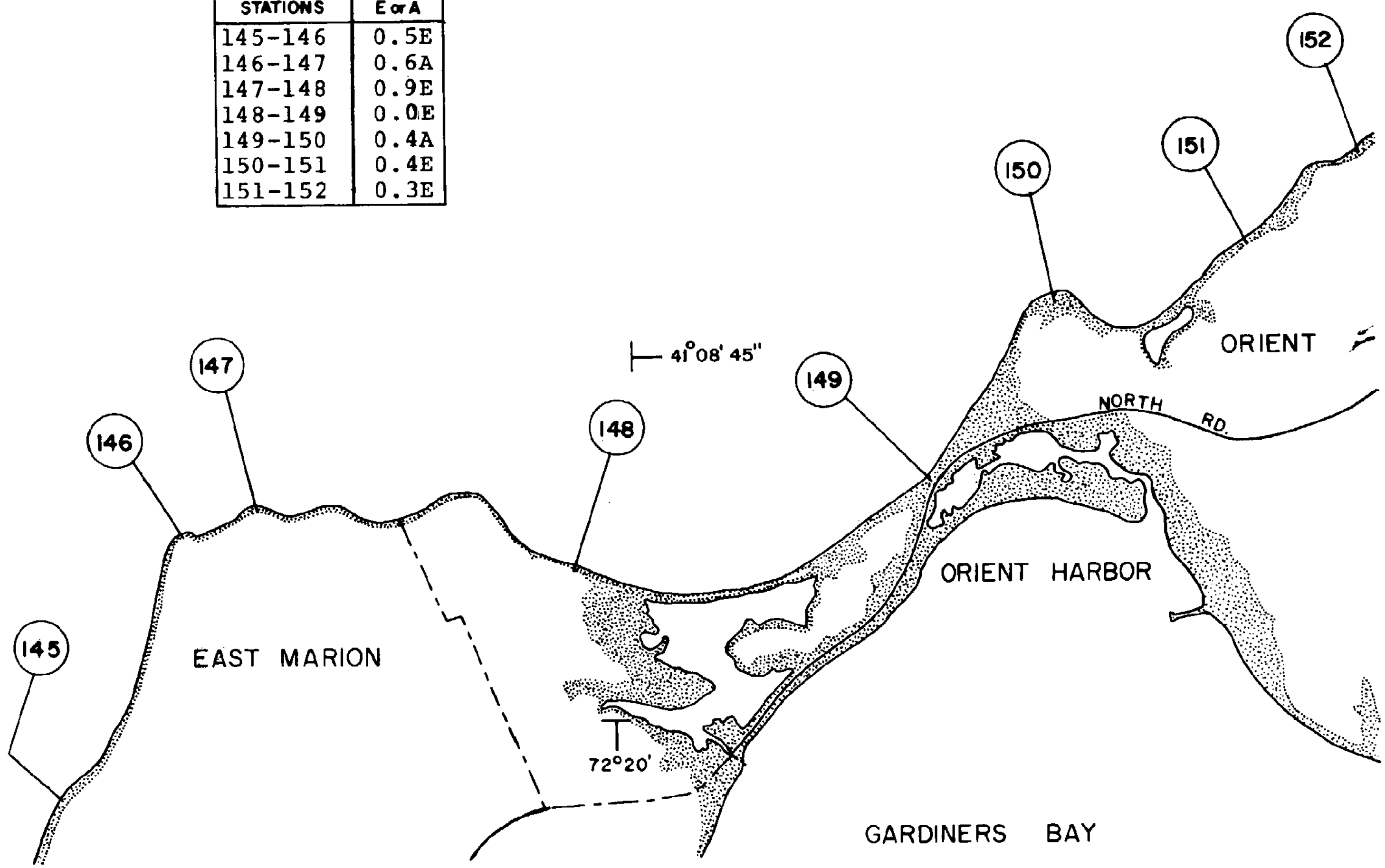


Fig. 3-29. Eastern Southold Township.

BETWEEN STATIONS	AVERAGE E or A
152-153	0.6E
153-154	1.3E
154-155	1.0E
155-156	0.2A
156-157	0.1E
157-158	0.0E

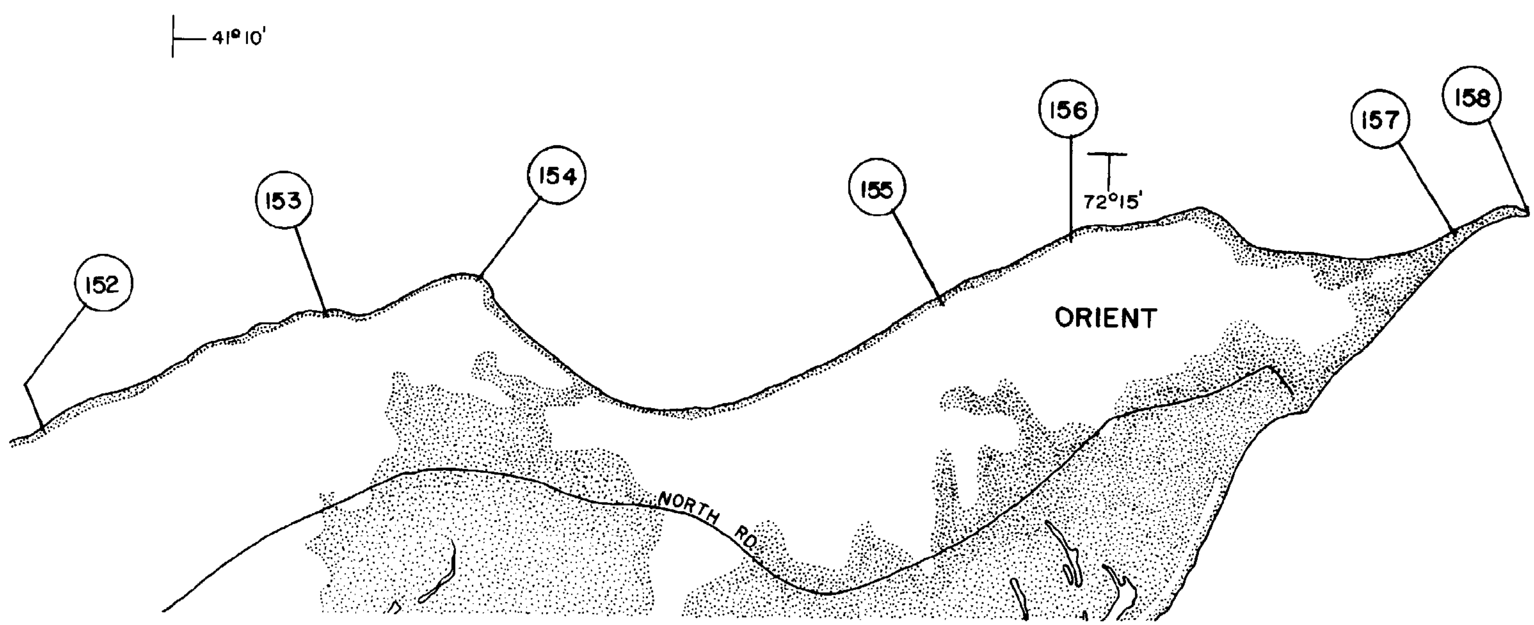


Fig. 3-30. Eastern Southold Township.

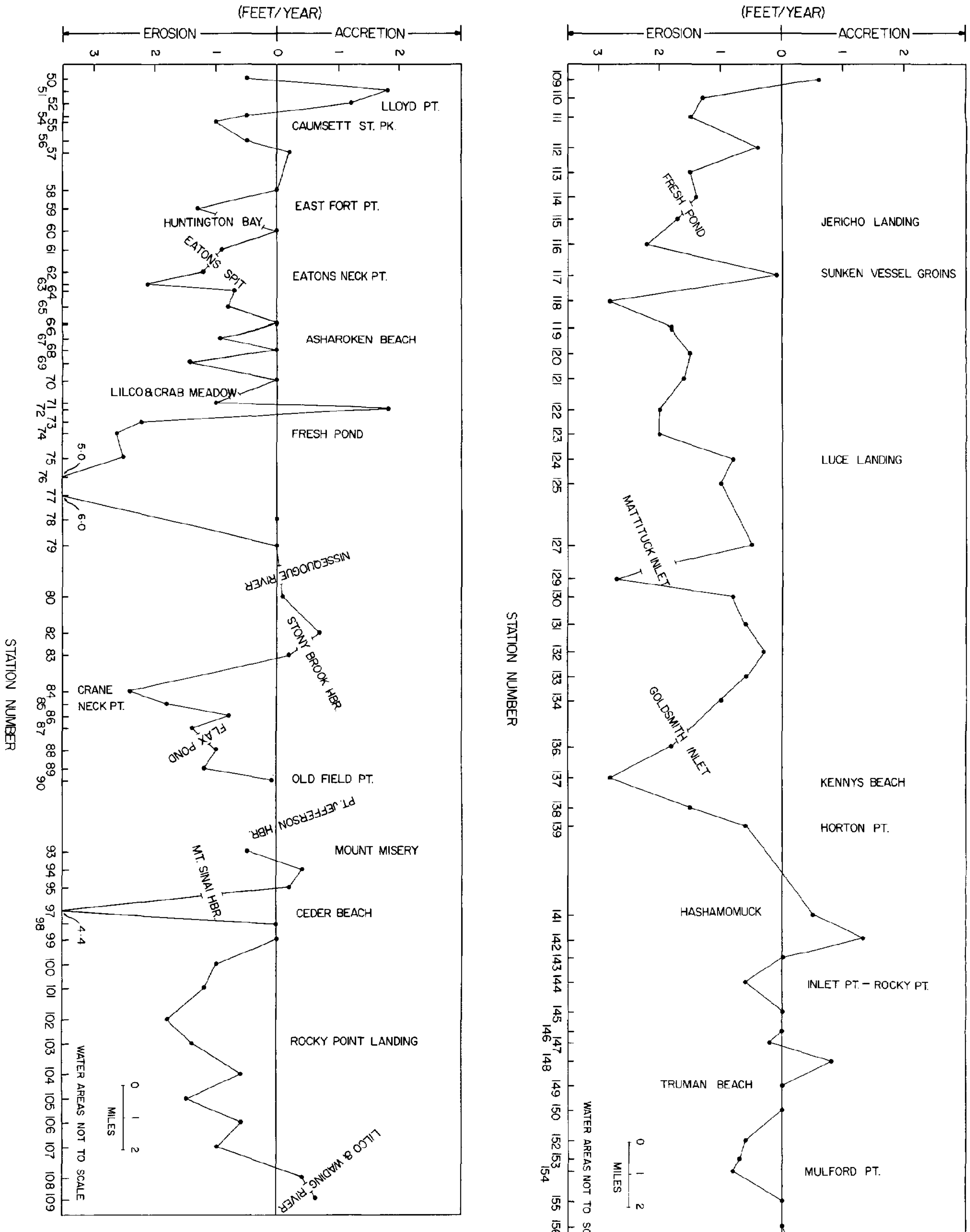


Fig. 3-31. Erosion and accretion rates.

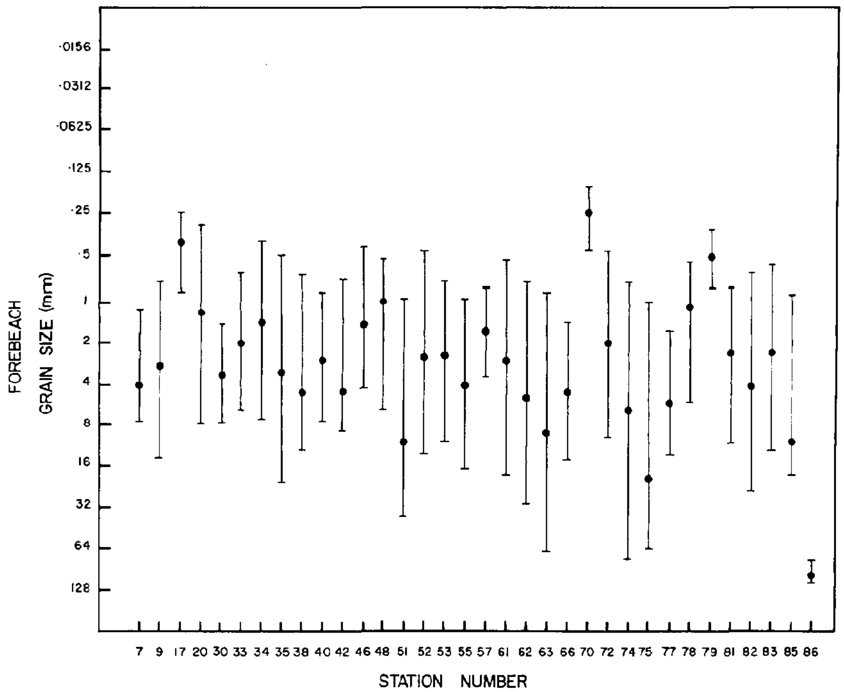


Fig. 3-32a. Forebeach grain size. Median grain sizes are indicated by dots, and the ranges shown include 68 percent of the total particle weight.

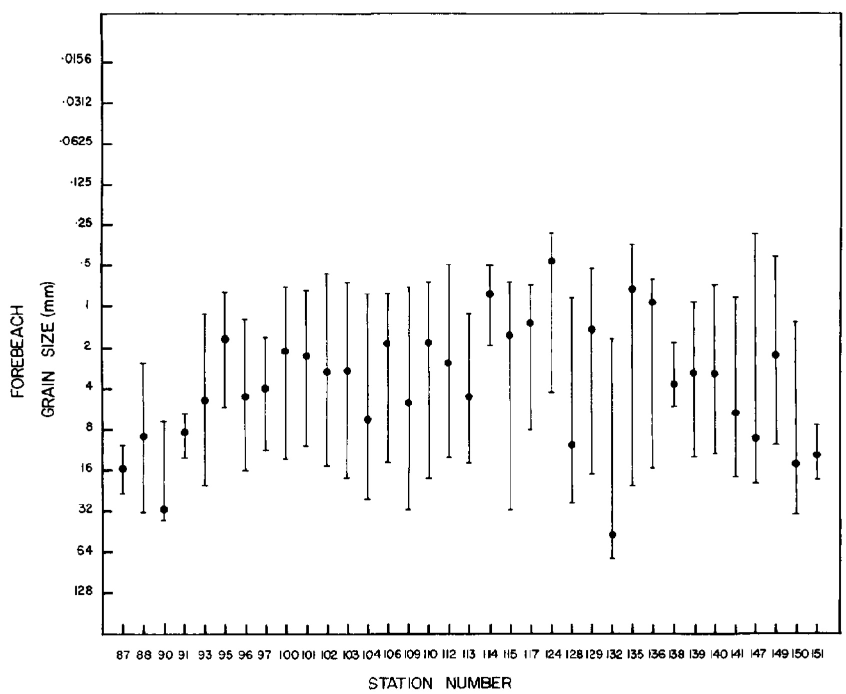


Fig. 3-32b. Forebeach grain size.

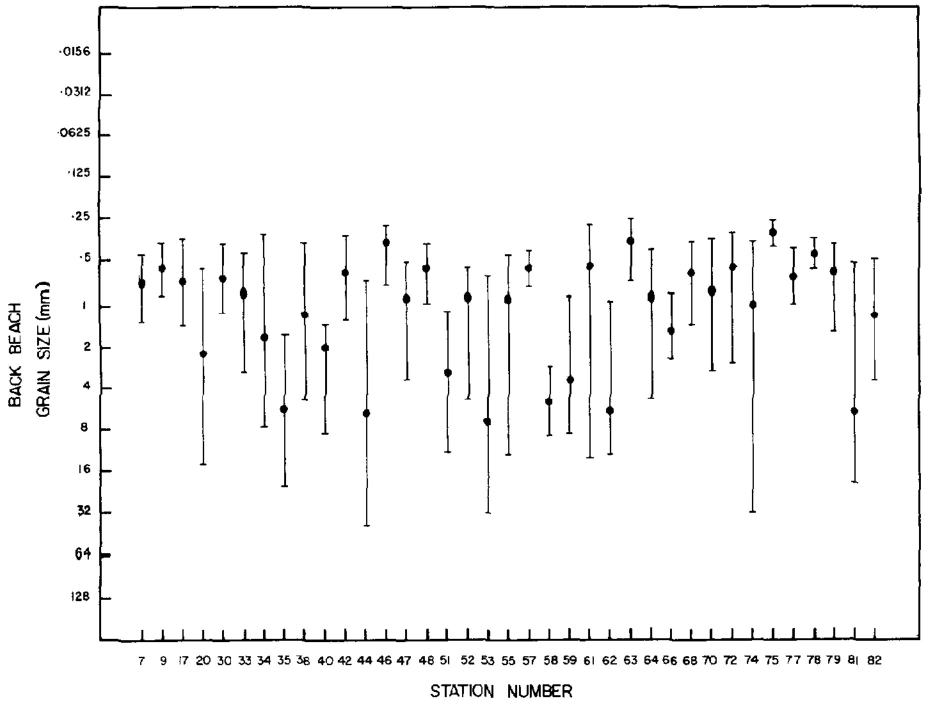


Fig. 3-33a. Backbeach grain size.

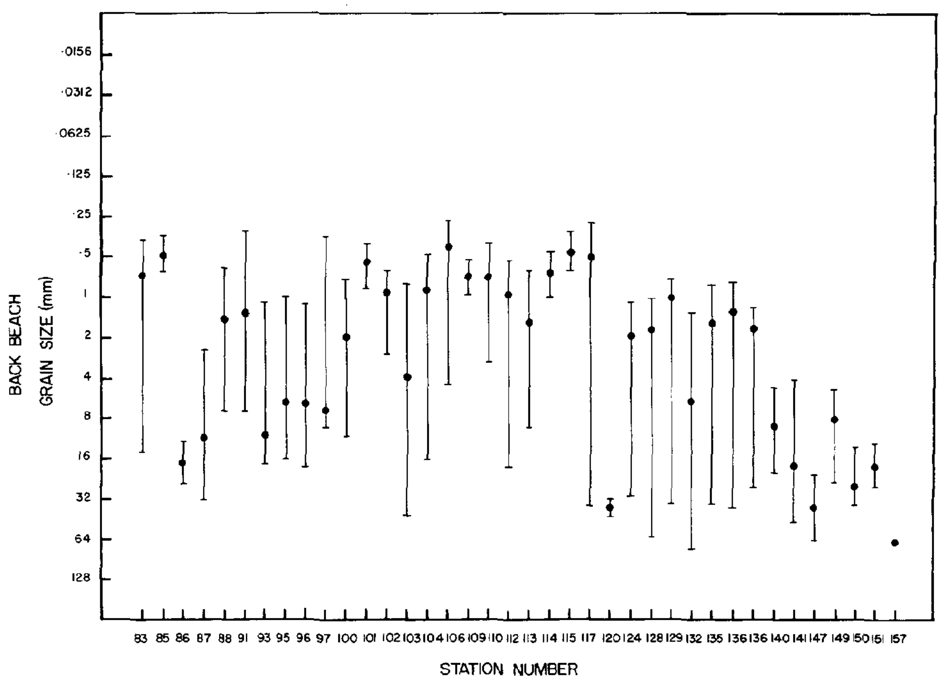


Fig. 3-33b. Backbeach grain size.

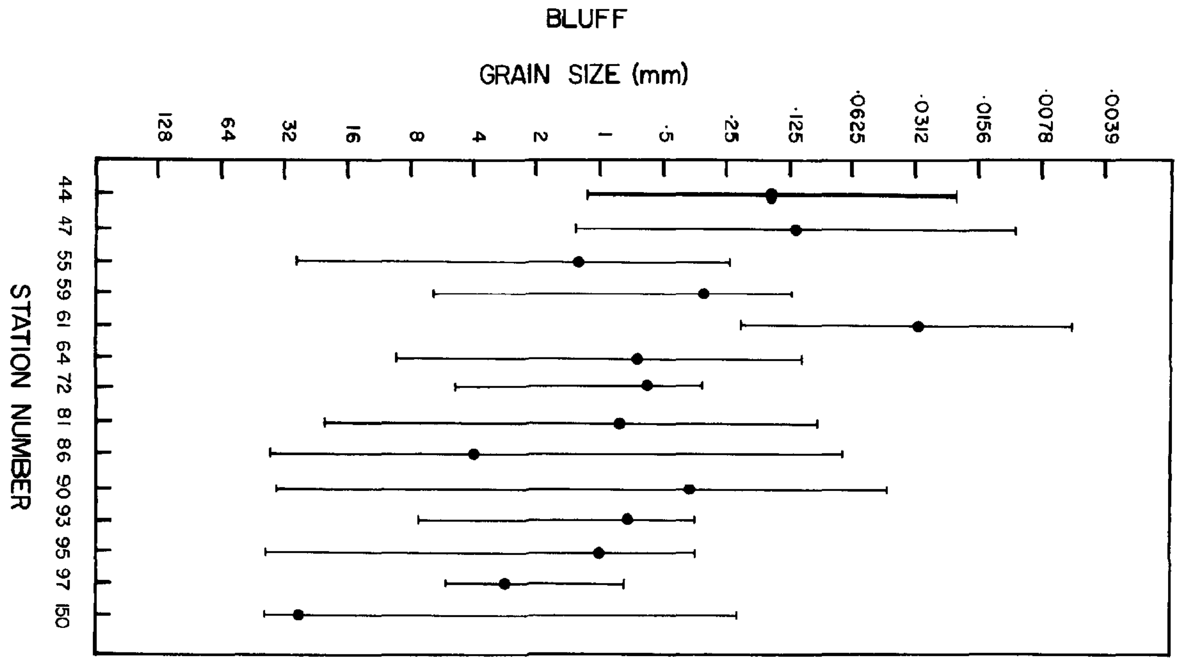


Fig. 3-34. Bluff grain size.

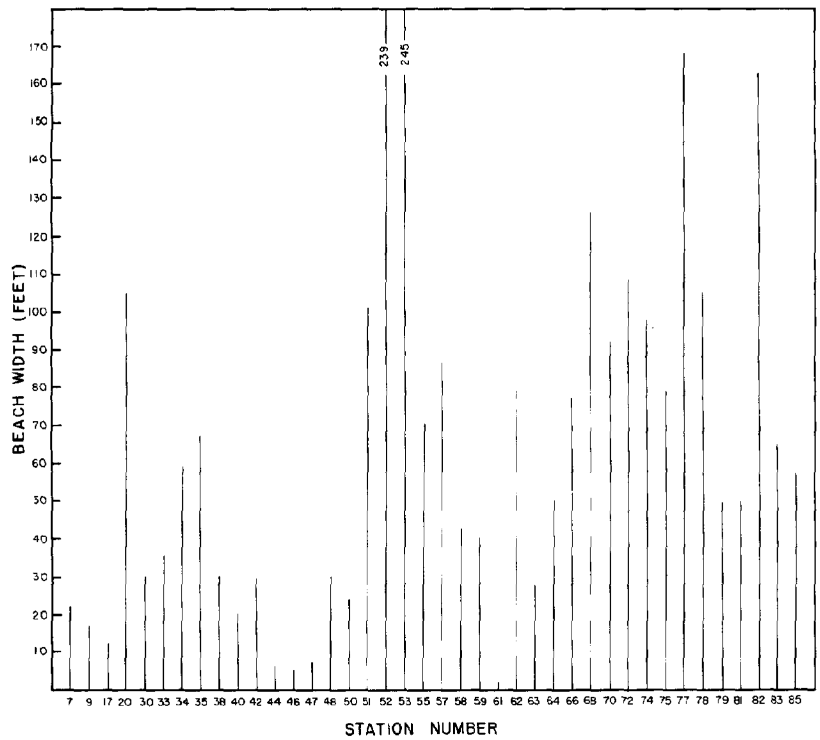


Fig. 3-35a. Beach width.

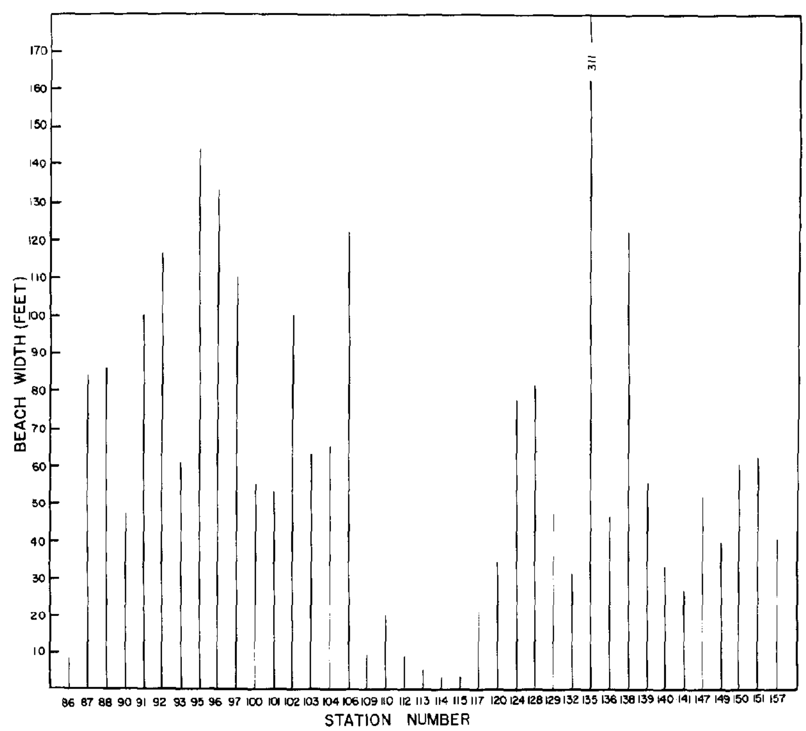


Fig. 3-35b. Beach width.

Fig. 3-36. Groin Buildup at Plum Point, North Hempstead Township.

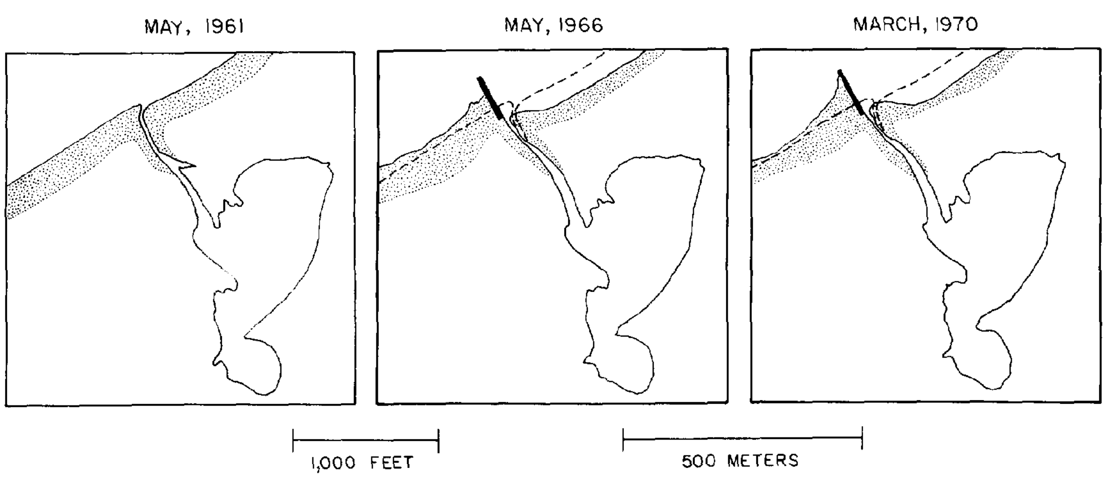


Fig. 3-37. Fort Goldsmith jetty, Southold Township, illustrating accretion updrift and erosion downdrift of Fort Goldsmith Inlet. Shoreline changes progress from before jetty construction (left) to two years after construction (center) and six years after construction (right). Dashed lines indicate the May 1961 shoreline.

Fig. 3-38. Concrete Bulkhead west of Hewlett Point, North Hempstead Township.

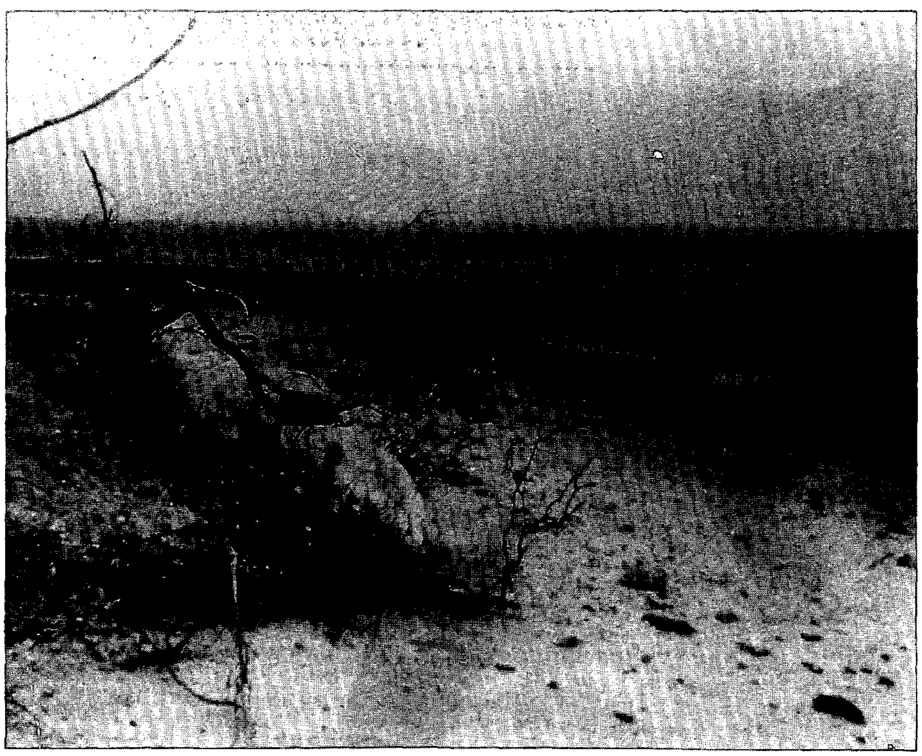


Fig. 3-39. Seawall at Centre Island, Oyster Bay Township.

Fig. 3-40. Eroding Bluffs at Lloyd Neck, Huntington Township.

Chapter 4

CRANE NECK - A CASE STUDY

Introduction

The Crane Neck region is chosen for a detailed study of shoreline trends. Much of the material for this Chapter is summarized from Davies (1972). The region is similar in many respects to other sections of the north shore, as it contains both bluffed coast and bar beach environments. Bluffs consisting of the Manhasset formation (Fuller, 1914) are exposed at the projecting headlands of Crane Neck Point and Old Field Point. Baymouth bars are found at West Meadow Beach, Flax Pond and Old Field Beach. The quantitative nature of accretion and erosion during an 80-year period of record at Crane Neck is used to illustrate the types of information that would be of value in developing a rational model of beach and erosion control management for the north shore of Long Island.

Several studies have been conducted on the erosion problem at Old Field Point. Teas (1956) stated that a lighthouse built at the Point in 1868 had to be abandoned in 1933 because of severe bluff recession. Both Teas (1956) and Tuthill (1959) believed that northeasters lasting for more than one tidal cycle could be as severe as hurricanes in producing shoreline damage. Saville (1956) suggested that the construction of a stone revetment 2287 m (7503 ft) in length would curtail erosion at the Point, only if the bluffs above the revetment were sloped, terraced and planted to prevent bank undercutting by storm waves and rain runoff. He felt that groins would be ineffective in creating a wide protective beach at the Point because the immediate vicinity lacks a large sand source. In 1964 a 229 m (751 ft) revetment with two groins was constructed (U.S. Army Corps of Engineers, 1969) to alleviate the erosion (2.6 ft per year) to the west of Old Field Point. The location of these structures is shown in Figure 4-1. The bluffs, however, were not terraced or planted. It is possible that these structures have influenced shore equilibrium to the east of Old Field Point, as an apparent increase in the rate of bluff recession has occurred in this area. A local resident claims the base of the bluff at Old Field Point receded about 2 m (7 ft) between 1967 and 1972. This increase in erosion rate may have resulted because the structures at the Point reduce the supply of sand to the beach east of the Point. A reduction in beach width would increase wave activity at the base of the bluff.

Other shore structures in the Crane Neck region are the jetties at Flax Pond and at the entrance to Port Jefferson Harbor. Two jetties stabilize tidal flow at Flax Pond. Previous to channel stabilization, the Flax Pond inlet migrated from west to east, indicating a net littoral transport in this direction in the area to the east of Crane Neck Point. A 214 m (702 ft) jetty constructed in the years 1876 to 1878 partially stabilized the migration of Old Field Beach at the entrance to Port Jefferson Harbor. The jetty caused a maximum of 134 m (440 ft) of accretion along 690 m (2264 ft) of beach west of the jetty. This indicated a net littoral drift from west to east in the vicinity east of Old Field Point. This is contrary to Saville (1956) who stated that littoral transport at Old Field Point was mainly from east to west. It is doubtful that littoral drift from the beaches at Belle Terre to the east of Port Jefferson Harbor would be able to cross the littoral barrier created by the harbor channel. Shoaling in the channel during the four-year period 1957 to 1961 amounted to about 2300 m^3 per year. This tentatively indicated the small carrying capacity of littoral currents in the region (U.S. House of Representatives, 1968).

The southern end of the bar at West Meadow Beach has been modified by the construction of six groins which are indicated in Figure 4-1. Spoil from dredging operations in Stony Brook Harbor was placed near the groins in 1951 and 1965 (U.S. Army Corps of Engineers, 1969, Appendix F). These modifications

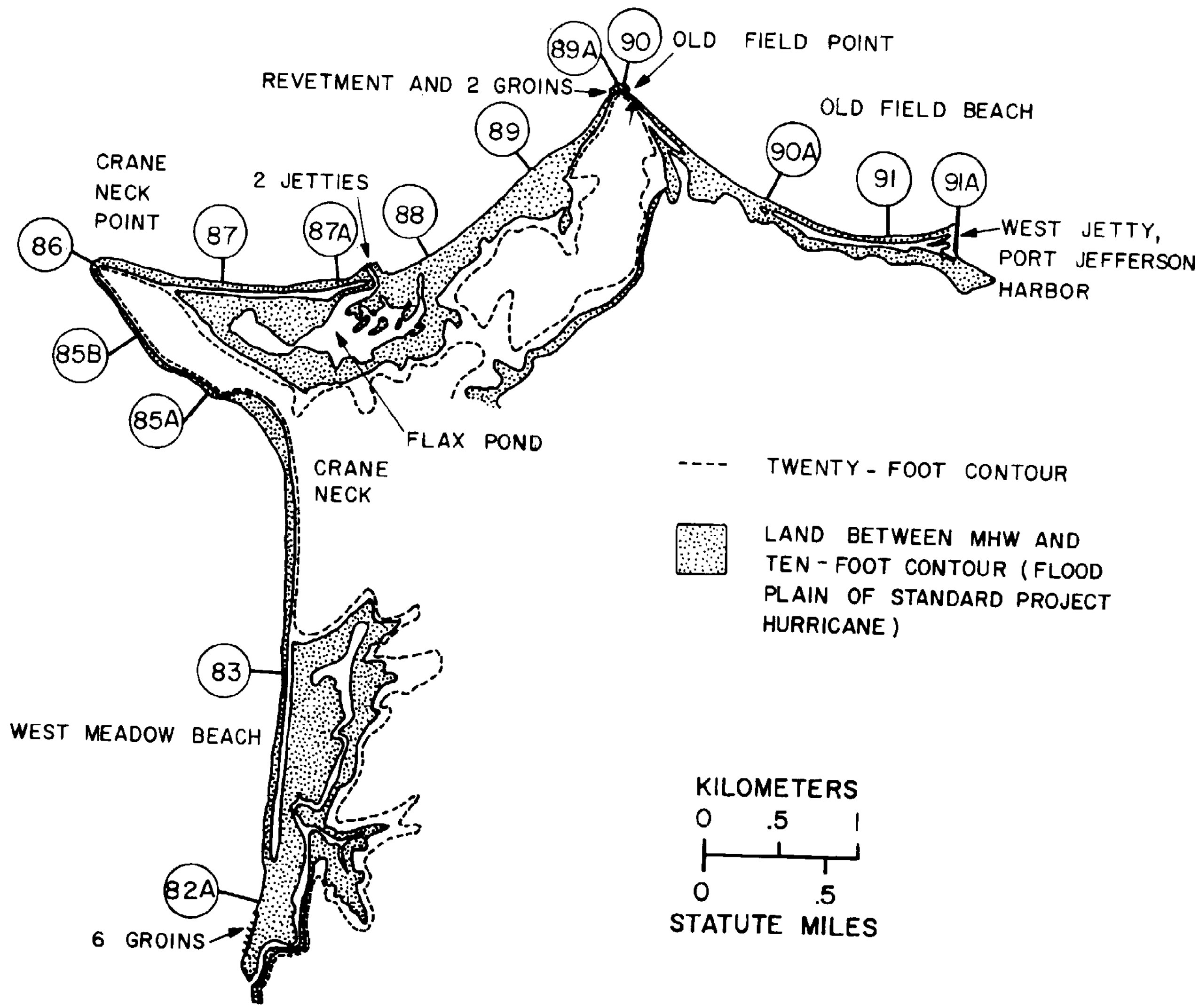


Fig. 4-1. Crane Neck, Brookhaven Town.

precluded use of this shoreline segment in the case study.

In the 1860s, approximately 15 to 20 thousand tons (9,900 to 13,000 m^3) of sand and gravel per year were removed from the beaches at Crane Neck and shipped to the New York City market (Adkins, 1955). The exact location and effects of this operation could not be determined.

Shoreline Erosion and Accretion

Shoreline changes during an 80-year period at Crane Neck were calculated at 14 selected stations along a total shoreline length of about 10 km (6 miles). Maximum erosion and accretion rates between stations were also determined as shown in Tables 4-1 and 4-2. The station intervals are shown in Figure 4-1.

Shoreline accretion occurred only at the bars. Over 2100 m (6900 ft) of shore at West Meadow experienced either an accretion of up to 34 m (112 ft) or no change in the position of the high water shoreline during the period of record. At Old Field Beach, 690 m (2264 ft) of shore to the west of the jetty at Port Jefferson Harbor advanced a maximum of 134 m (440 ft). Both these areas are receiving an amount of littoral drift equal to or greater than that which is removed.

Erosion occurred along 7415 m (24,325 ft) of shore (72 percent of the Crane Neck shore length). The largest recession, 81 m (266 ft), occurred in the region just north of profile 85a. Several locations between Crane Neck Point and Old Field Point experienced recessions up to 34 m (112 ft). The large recession at the western part of Old Field Beach 56 m (184 ft) may partially be explained by barrier bar migration to the south. It is interesting to note that maximum erosion rates were displaced away from the tips of the Old Field and Crane Neck Points. This may be explained by the process of wave refraction occurring at these headlands (U.S. Army Coastal Engineering Research Center, 1966). Eroding beach segments supply sediment to other areas, as they lose more material than they receive.

Figure 4-2 shows a plot of erosion and accretion rates at various locations versus shoreline distance. Zones of active erosion occur as troughs on the plot; zones of active accretion occur as peaks. Such a plot can help indicate the best locations for attempts to build up or maintain a beach, by groin fields or beach nourishment. The troughs in the plot represent locations where shore protection practices would necessarily be most extensive and, generally, most expensive.

Calculations of area change during the 80-year period of record reveal that there was a total net erosion of 187,300 m^2 (46.4 acres) of land over the entire shoreline length studied. This net erosion represents a significant loss in shorefront property. As expressed in Table 4-1, those station intervals with average annual erosion rates of over 1.0 ft per year appear to be areas of high risk for the development of beach property. Locations with lower erosion rates, or those areas experiencing accretion, are better suited for development because of the lower risk involved. It should be kept in mind that this method of assigning a risk category to an area is based on the single criterion of past shoreline history. Other criteria, such as frequency of storm surge flooding, must also be considered in developing a comprehensive damage-susceptibility index.

Flood Plain Zoning

Flood plain zoning is a technique that has been used to reduce potential property losses due to wave and tide action in coastal areas (U.S. Water Resources Council, 1971, Vol. II, p. 19). Flood plain zoning codes regulate construction

Table 4-1 ESTIMATES OF EROSION AND ACCRETION, CRANE NECK, NEW YORK, 1885 to 1965

Station Interval	Shore Length (m)	Shore Length (ft)	Net Accretion (A) or Net Erosion (E) (m^2)	Average Annual Accretion (A) or Erosion (E) (m)	Average Annual Accretion (A) or Erosion (E) (ft)	Maximum Annual Erosion (m)	Maximum Annual Erosion (ft)
82a-83	1535	5035	9,670 (A)	0.1 (A)	0.3 (A)	0.4	1.4
83-85a	1965	6445	31,420 (E)	0.2 (E)	.7 (E)	0.7	2.4
85a-85b	565	1855	22,350 (E)	0.5 (E)	1.6 (E)	1.0	3.3
85b-86	490	1610	19,330 (E)	0.5 (E)	1.6 (E)	0.6	1.8
86-87	740	2430	14,500 (E)	0.2 (E)	0.8 (E)	0.4	1.4
87-87a	740	2430	24,170 (E)	0.4 (E)	1.3 (E)	0.4	1.4
87a-88	520	1705	730 (A)	0.0 (A)	0.1 (A)	0.3	1.0
88-89	860	2820	16,915 (E)	0.3 (E)	0.8 (E)	0.4	1.4
89-89a	740	2430	18,125 (E)	0.3 (E)	1.0 (E)	0.4	1.4
89a-90	25	80	0 (E)	0.0 (E)	0.0 (E)	0.0	0.0
90-90a	1080	3545	44,715 (E)	0.5 (E)	1.7 (E)	0.7	2.4
90a-91	835	2740	26,590 (E)	0.4 (E)	1.3 (E)	0.6	1.8
91-91a	690	2265	21,145 (A)	0.4 (E)	1.3 (A)	0.0	0.0

Table 4-2. EROSION AND ACCRETION SUMMARY, CRANE NECK, NEW YORK

Shoreline Section	Length (m)	Length (ft)	Net Erosion (m^2)	Average Annual Erosion (m)	Average Annual Erosion (ft)	Maximum Annual Erosion (m)	Maximum Annual Erosion (ft)	Length Eroding (m)	Length Eroding (ft)	Length Accreting (m)	Length Accreting (ft)	Length Stable (m)	Length Stable (ft)
West Meadow Beach to Crane Neck Point (82a-86)	4,555	14,944	63,430	0.17	0.56	1.01	3.32	2,420	7,940	1,510	4,954	625	2,050
Crane Neck Point to Old Field Point (86-90)	3,080	11,734	73,710	0.30	0.98	0.42	1.40	3,080	10,104				
Old Field Point to West Jetty, Port Jefferson Harbor (90-91a)	2,605	8,547	50,160	0.24	0.79	0.70	2.30	1,915	6,283	690	2,264		
TOTAL	10,240	35,225	187,300	0.22	0.72	1.01	3.32	7,415	24,327	2,200	7,218	625	2,050

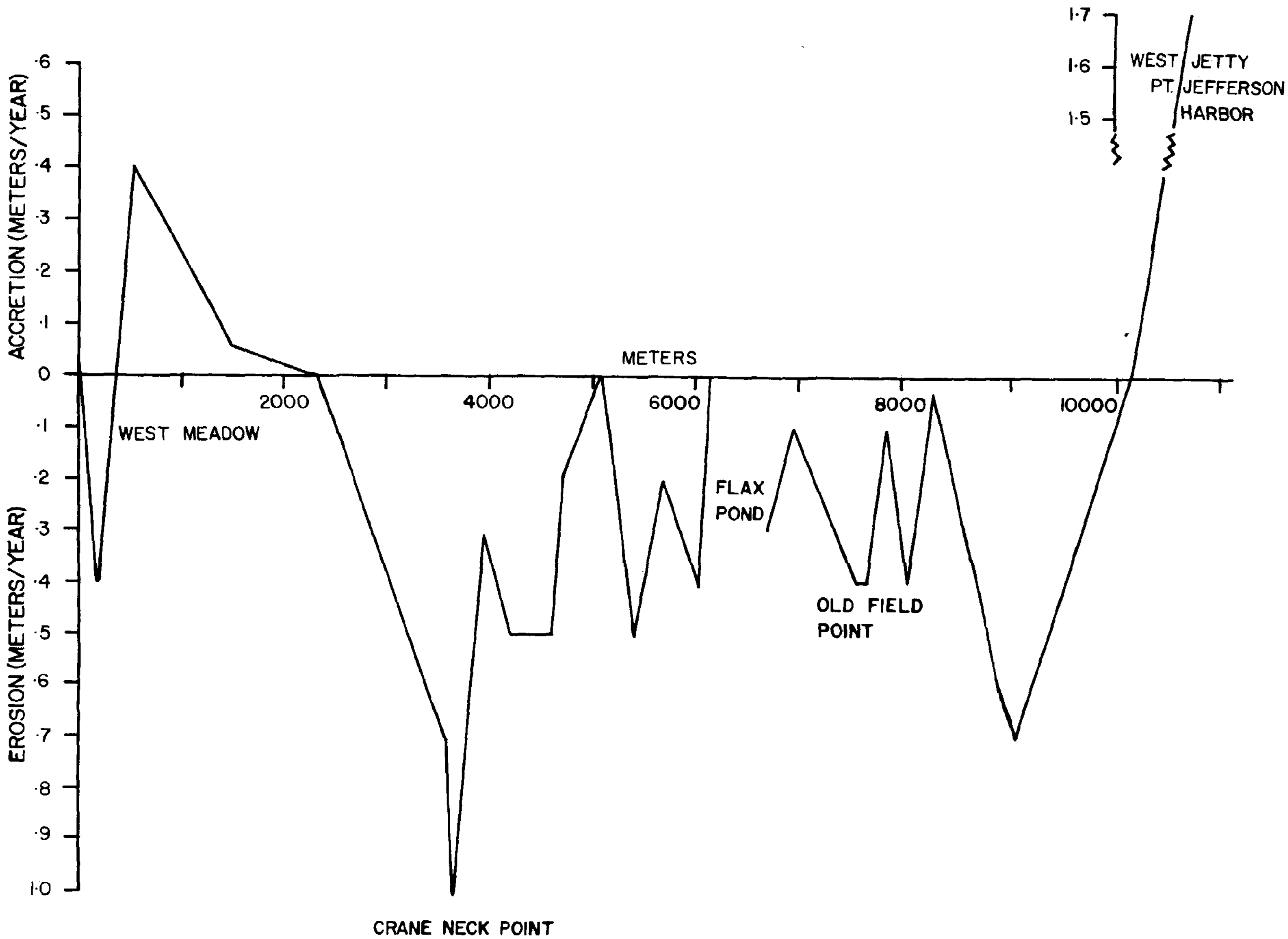


Fig. 4-2. Erosion and accretion rates at Crane Neck.

near the shoreline. To establish a coastal flood plain requires definition of those areas subject to tidal flooding during storms. The relative frequency of storm tides at Stratford, Conn. is shown in Figure 4-3. This frequency curve would also hold for locations on Long Island's coast near Port Jefferson (U.S. Army Corps of Engineers, 1969). A storm tide such as that produced by the September 21, 1938 hurricane is likely to occur once every 30 years. A tide of 4 m (13.2 ft) above mean sea level has been designated as the standard project hurricane tide for the Port Jefferson area. The standard project hurricane is a "hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region" (U.S. Army Coastal Engineering Research Center, 1966, p. A-17). The characteristics of the September 14, 1944 hurricane were used to calculate the standard tide.

Areas subject to inundation by the standard project hurricane tide at Crane Neck are identified in Figure 4-1, having been determined by the location of the 3 m (10 ft) contour. This flood plain boundary is a conservative estimate, because flooding from a standard project tide would extend inland to elevations greater than 4 m (13 ft) above mean sea level. In addition, hurricane waves can drastically increase water levels at the shore. A wave will usually penetrate inland a distance approximately equal to its wave length from the mean water level (U.S. Water Resources Council, 1971, Vol. II, p. 132). Large hurricane waves have the potential for inundating elevations higher than 4 m (13 ft), especially in those areas directly on the Sound, such as the bars at West Meadow, Flax Pond and Old Field Beach.

Offshore Depth Changes at Crane Neck

Changes in the position of offshore depth contours recorded in 1885 to 1886 and in 1965 reveal trends in the direction of contour movement. At the projecting headlands of Crane Neck and Old Field Points (Stations 86, 89a, and 90) the offshore depth contours of 1965 were displaced seaward from their positions in 1885 to 1886. At the bar environments at West Meadow Beach and Old Field Beach (Stations 83 and 90a) there was a trend for the offshore depth contours to move landward during the period of record.

Volume changes along Stations 86, 89a, and 90a to a depth of 9 m (30 ft) were determined for the period of record by comparing beach profiles measured in 1965 by the U.S. Army Corps of Engineers (1969) with our profiles determined from 1885 to 1886 Coast and Geodetic Survey charts. The depths were determined directly from the 1885 to 1886 charts (Figs. 4-4 to 4-6). To construct the 1885 to 1886 beach profiles, recession of the bluff face or dune crest was assumed to coincide with the recession of the high water shoreline and the erosion of the beach was assumed to occur along a "profile of erosion" maintaining its form as it shifts towards land (Zeigler et al., 1964). In this way the profile could be projected seward a distance equal to the erosion during the period of record, and with the location of the 1885 to 1886 offshore depth contours, the areas of cut and fill along the profiles during the 80-year period could be ascertained. The areas were converted to volumes by assuming a profile width of 1 m. The seaward limit of the profiles, 9 m (30 ft), was believed to be a boundary within which the bulk of littoral sediment movement took place. Cut and fill information is shown in Table 4-3.

At Stations 86 and 90a the amount of material that is eroded from the beach is more than that which is deposited at locations offshore. Therefore, part of the material eroded at these stations is supplied to other areas along the shore. At Station 89a, over three times the amount of material eroded from the shore is deposited along sections of the station. This means that the area is receiving more sediment from adjacent areas than it is losing. More detailed surveys of

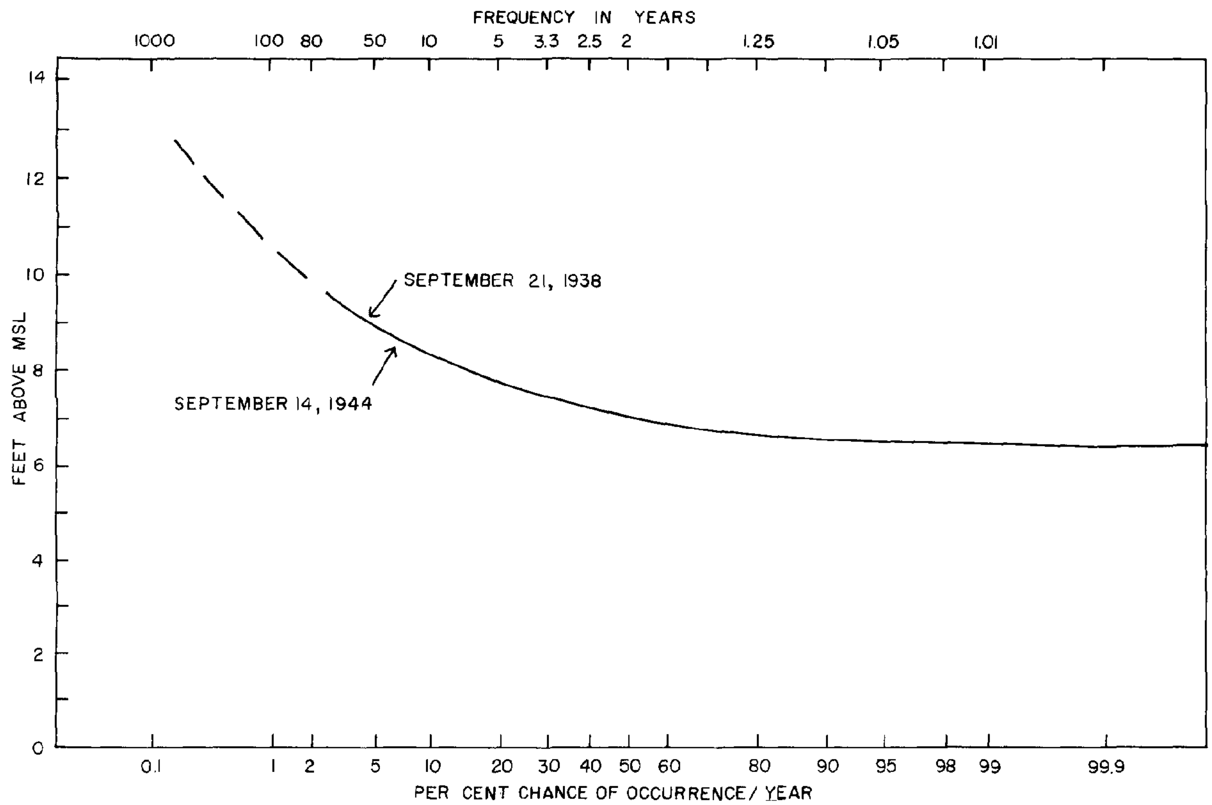


Fig. 4-3. Storm tide frequency at Stratford, Connecticut. (U.S. Army Corps of Engineers, 1969, Fig. C19).

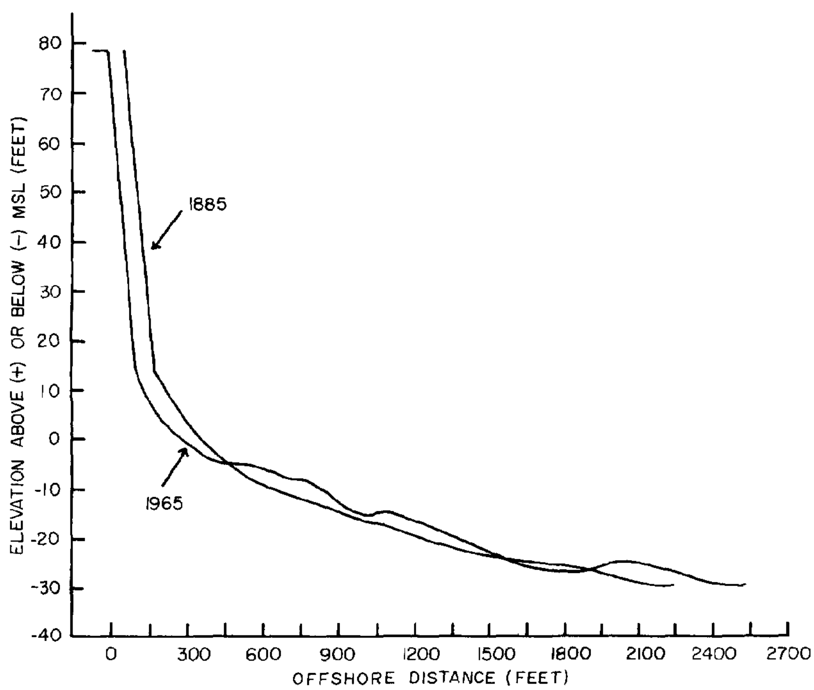


Fig. 4-4. Shore cross section at Station 86, Crane Neck.

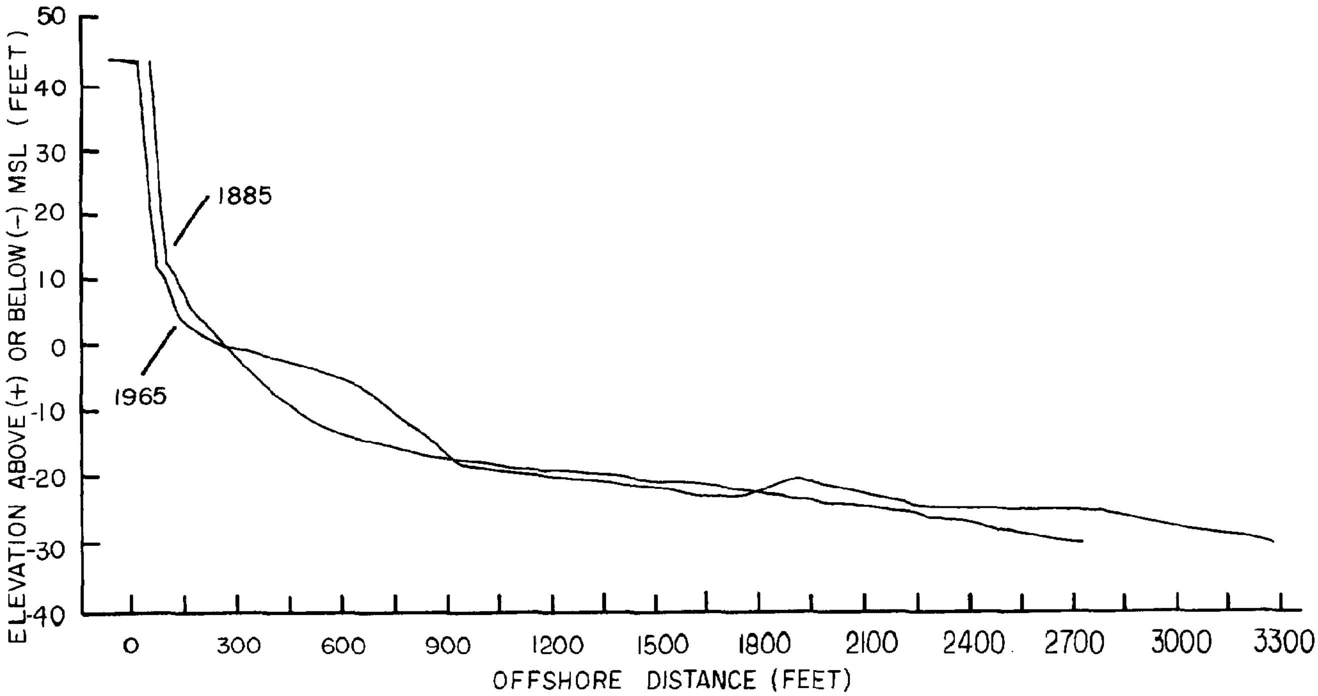


Fig. 4-5. Shore cross section at Station 89a, Crane Neck.

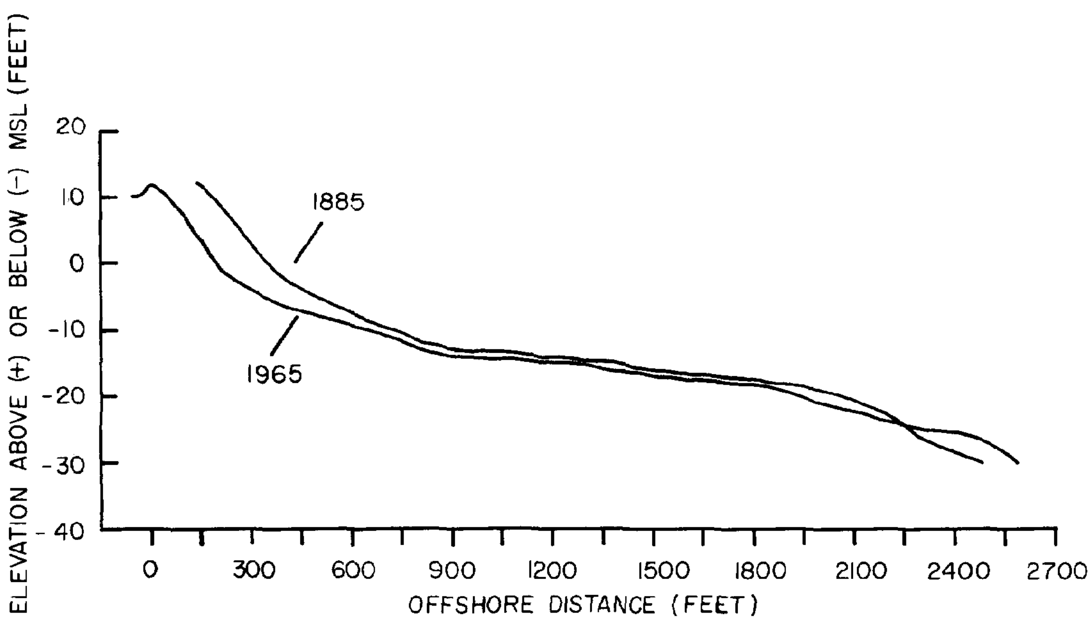


Fig. 4-6. Shore cross section at Station 90a, Crane Neck.

changes in closely spaced stations over short periods of time are required to better evaluate the movement of material near the shore.

Table 4-3. VOLUMETRIC CUT AND FILL, SELECTED PROFILES, CRANE NECK, NEW YORK

Profile	Net Cut m^3	Net Fill m^3	Percent Loss	Percent Gain
86	592	420	29	
89a	204	616		202
90a	441	106	76	

Sand Sources at Crane Neck

The eroding bluffs at Crane Neck and Old Field Points are the major sources of sand supplying the nearby beaches. A rough estimate of the amount of material delivered to the beach environment from the eroding bluffs has been determined as follows:

Bluff Location	Crane Neck Point	Old Field Point
length of eroding bluffs	1440 m (4720 ft)	720 m (2360 ft)
average bluff height	21 m (69 ft)	9 m (30 ft)
bluff recession rate	0.5 m per year (1.6 ft per year)	0.5 m per year (1.6 ft per year)
contribution of bluff sediment	15,000 m^3 per year	3,000 m^3 per year

Thus, about 18,000 m^3 of sediment are expected to enter the beach environment during a year, while the bluffs recede an average horizontal distance of 0.5 m (1.6 ft) along their entire length.

The Crane Neck bluffs consist of the Montauk till member of the Manhasset formation, which is a mixture of quartz and clay rock flour, coarse sands, pebbles and boulders (Fuller, 1914). The large boulder, 6 m (20 ft) in diameter, now located at the Beach at Crane Neck Point was seen embedded in the till of the bluff face by Fuller (1914) in the early part of this century. A trench sample of the bluff face at Old Field Point was taken for the purpose of sediment grain size analysis. The results of that anlysis are shown in the histogram in Figure 4-7. The histogram does not accurately represent the larger size grades, for cobbles (64 to 256 mm) and boulders (greater than 256 mm) present in the glacial till were not in the sample analyzed. The distribution of coarse sands and finer fractions is, however, probably accurately represented. The till was found to be very poorly sorted, with relatively large amounts of both very coarse sand and coarse silt. Over 36 percent of the total sample by weight consisted of silts and clays.

The beach adjacent to the bluff at Old Field Point was also sampled for grain size analysis, and the histogram is shown in Figure 4-8. Again, the coarse fraction of cobbles and small boulders was not sampled. A grab sample was taken of the finer beach sediments found in the intertidal zone. These sediments were poorly sorted, and consisted mainly of pebbles (16 to 64 mm) and granules (2 to 4 mm). Less than one percent by weight of the beach sample consisted of silt

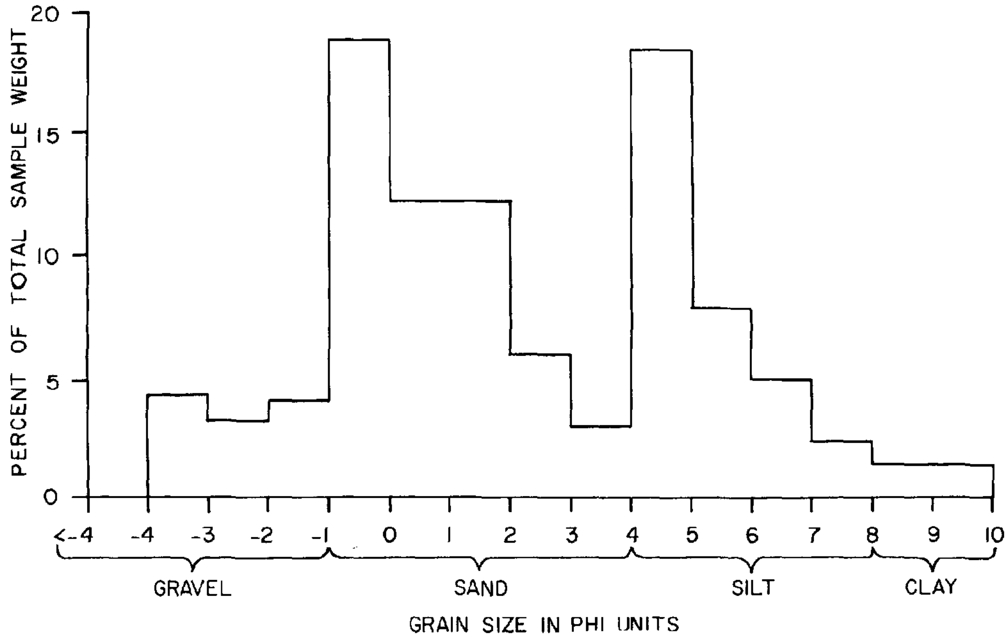


Fig. 4-7. Grain size analysis of the bluffs at Old Field Point.

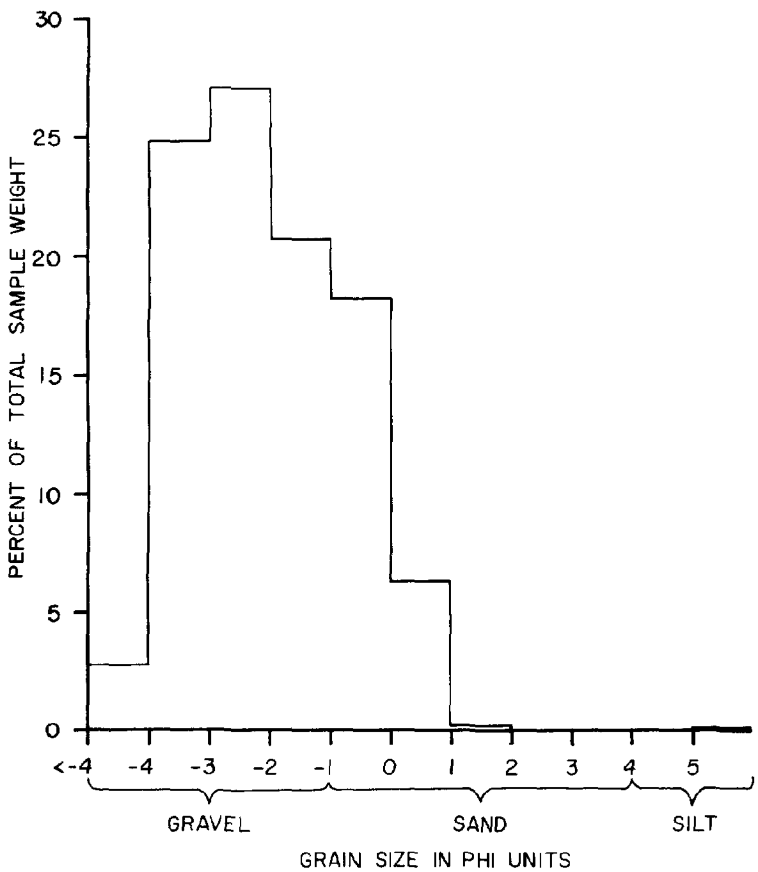


Fig. 4-8. Grain size analysis of the beach at Old Field Point.

and clay. The change in grain size distribution between the bluffs, which are a source of beach sand, and the beach shows the effectiveness of wind and wave action in removing the silts and clays from the near-shore environment. Over 50 percent by weight of the bluff sediments are removed from the beaches, leaving behind a lag deposit of granule and coarser fractions. The silts and clays are lost either to offshore areas in central Long Island Sound, or inland because of wind deflation. The results of this sorting action are also shown in the grain-size distribution maps of Krebs (1963) for the offshore area west of Crane Neck.

Thus the bluffs of the Crane Neck region are not supplying as much material to the beach as one might expect. More than half the material in the bluffs is of small grain sizes which are incapable of remaining in the high energy beach environment. Much of the remaining portion consists of fractions larger than very coarse sand. Roughly 20 percent of the bluff material consists of very fine to medium sands, that fraction most capable of being transported alongshore as littoral drift. The relatively small amount of very fine to medium sand available explains why groins would be ineffective in building up large beaches in those sections of the Crane Neck region backed by bluffs.

The glacial deposits which underlie the beaches and bars are the other primary source of sediment at Crane Neck. The surface of this glacial material corresponds to the "profile of erosion" of Zeigler et al. (1964). The bluff face is the subaerially exposed part of the profile of erosion. The bluff face is cut back by both storm and "normal" weather activity. "Normal" weather refers to weather conditions which do not produce extreme high tides and waves capable of producing direct bluff attack. Cutting of that portion of the erosion profile which is not subaerially exposed can occur only during severe storms which shift the surface cover of beach sediments, exposing the uneroded glacial deposits to direct wave action. Long-term landward movement of the entire profile of erosion therefore results mainly from storms. Short-term changes in the configuration of the beaches which mantle the erosion surface are not only the result of storms, but also of "normal" weather conditions.

Zeigler et al. (1964) estimate that Cape Cod beaches receive roughly 50 percent of their sand supply from eroding bluffs, with the remaining 50 percent supplied from the erosion of glacial sediments below sea level. These estimates refer to the "new" sediment entering the beach system, and do not include sediment carried as littoral drift. It is not possible at this time to determine the quantity of sediment derived from the offshore areas that nourishes the beaches at Crane Neck. The bluffs appear to be the major source of sediment. Zeigler et al. (1964) determined that if the bluffs at Cape Cod were completely stabilized, the reduction in sand nourishment would cause the beaches to entirely disappear in 86 years. A similar relation probably holds true for the north shore of Long Island.

Use of Beach Utility Index

The utility index described in Chapter 3 can be used to locate beach areas amenable to development. The following considerations are important:

1. A beach which is accreting or subject to moderate erosion provides greater protection to fixed structures than a beach which is subject to severe erosion.
2. Areas fronted by high, stable bluffs or dunes have effective storm protection provided by these barriers.
3. Wide beaches offer more space for recreation and greater protection from possible storm wave attack for inland areas.

4. Beaches consisting predominantly of sand size sediment are considered better for recreation than gravel or cobble beaches, because of the greater difficulty in walking with bare feet on beaches consisting of the larger grain sizes.

5. Beaches and near-shore areas that are easily accessible by public roads which do not disturb residential areas, and that provide ample space for parking are more suitable for recreational development than inaccessible areas.

The application of the beach utility index to the Crane Neck area results in the following conclusions:

1. Beach development at either Crane Neck or Old Field Points (Stations 89 and 90) is not advisable because of poor access, narrow beach widths and the large grain size of the beach sediments.

2. Construction of permanent structures between Crane Neck and Old Field Points (Stations 87, 88 and 89) is not advisable because of the potential erosion hazard. Very limited recreational usage can perhaps be accommodated, with particular attention focused on the protection of vegetation on the baymouth bars and in the Flax Pond wetlands.

3. Poor access limits the use of Old Field Beach (Station 91) to recreational boaters. Again, adequate measures will have to be taken to protect wetland vegetation.

4. West Meadow Beach and the area immediately to the north (Stations 83, 84 and 85) offer the best options for future recreational development. Access is adequate, and space for parking could be expanded by acquisition of adjacent land. The beach is wide and tends to consist of finer beach sediments. However, at Stations 84 and 85, due to high rates of shoreline erosion, little or no permanent construction should take place on the beach.

Chapter 5

METHODS

Littoral Drift

The predominant direction of littoral transport can be determined by the following methods (U.S. Army Corps of Engineers Coastal Engineering Research Center, 1966):

1. Observation of erosion and accretion effects at existing shore structures is the most reliable means of determining the direction of littoral transport. However, care must be taken not to confuse short-term effects with the long-term situation. The erosion and accretion associated with significant shore structures, such as jetties, can be generally taken to indicate the predominant transport direction.
2. Headland configuration and its relationship to spit formation and the location of pocket beaches gives an indication of the predominant littoral transport direction. Spits and pocket beaches develop in the downdrift direction from eroding headlands.
3. The migration of a tidal inlet or stream delta over long periods of time will tend to be in the direction of littoral drift. As such, unprotected channels are offset in a downdrift direction.
4. Variation of median grain size along a beach can give an indication of sediment transport; the median grain size will decrease with increasing distance from the source of the sediment, if sediment from another source is not introduced into the beach zone.

The above methods were used to determine the directions of littoral transport along the north shore of Long Island shown in the fold-out map at the end of the report. Field observations, 1970 aerial photographs supplied by the Nassau-Suffolk Regional Planning Board, and maps of shoreline trends supplied by the New York District, U.S. Army Corps of Engineers, were used. Other determinations of longshore transport direction, such as analysis of wave energy components and current measurement, were not used.

Base Maps and Station Determination

The base maps were traced from the most recent 7 1/2 minute quadrangle maps of the United States Geologic Survey.

Field station locations in Suffolk County were the same, where possible, as those of the U.S. Army Corps of Engineers (1969) study of the "North Shore of Long Island, Suffolk County, New York." (See Table 5-1 for the equivalent station numbers of both studies.) Field stations in Nassau County were chosen to give approximately the same station density.

To study erosion and accretion we added stations between the field stations in both Nassau and Suffolk Counties.

Erosion and Accretion

Several techniques can be utilized to estimate erosion and accretion for shoreline areas (Stafford, 1971). Aerial photographs supplied by the Nassau-Suffolk Regional Planning Board were not used, because scale variations on the photographs were of sufficient magnitude to obscure actual shoreline trends in the relatively short period of time between sets of photographs. Instead, old

Table 5-1 U.S. ARMY CORPS OF ENGINEERS (1969) STATIONS AND THE EQUIVALENT BI-COUNTY STATIONS

Army Corps	Bi-County	Army Corps	Bi-County	Army Corps	Bi-County	Army Corps	Bi-County
1	50	21	-	41	100	61	138
2	51	22	74	42	101	62	139
3	52	23	75	43	102	63	-
4	-	24	77	44	103	64	140
5	54	25	78	45	104	65	141
6	55	26	79	46	106	66	147
7	56	27	80	47	109	67	148
8	-	28	82	48	111	68	150
9	-	29	83	49	112	69	153
10	58	30	84	50	113	70	157
11	-	31	86	51	114		
12	61	32	87	52	115		
13	62	33	88	53	117		
14	63	34	-	54	120		
15	64	35	90	55	124		
16	66	36	91	56	128		
17	67	37	92	57	129		
18	68	38	93	58	132		
19	69	39	95	59	135		
20	70	40	97	60	136		

maps and charts were compared with recent editions to provide quantitative estimates of shoreline trends. Erosion and accretion rates at the selected stations along the north shore of Suffolk County were calculated by comparing the position of the high water shoreline found on U.S. Coast and Geodetic Survey charts surveyed in 1885 to 1886 with those of 1965 base maps compiled by the U.S. Army Coastal Engineering Research Center. Because the U.S. Army Corps of Engineers (1969) transposed the 1885 to 1886 charts on the 1965 base maps, the area of erosion or accretion between stations could be determined. By dividing this area by the length of shoreline between stations, the average erosion or accretion rates between stations were determined. Rates of change at stations on Nassau County's north shoreline were similarly derived using surveys made in 1886 and making comparisons with 1970 surveys. However, for Nassau County the 1886 charts were not transposed on the 1970 charts and consequently the area changes between stations could not be determined. At the station locations in both Nassau and Suffolk Counties, estimates of erosion and accretion between survey dates were divided by the 80-year time interval to derive annual erosion or accretion rates.

The estimated erosion and accretion rates are subject to many possible inaccuracies, such as errors caused by surveying techniques and lack of horizontal control while making map comparisons. The general trends, however, are believed to be valid. The rates reflect only net shoreline changes during the period of record and, therefore, short-term changes may not be observed. As an example, the high water shoreline at a particular profile could have eroded 30 m (98 ft) during the first 20 years of record, and then accreted 20 m (66 ft) during the next 10 years of record, to give a total net recession of 10 m (33 ft) and a calculated average erosion rate of 0.3 m (1 ft) per year for the 30-year period of record. The fact that the shore did experience accretion during the period of record is not reflected in the rate calculated.

Flood Plain

We determined the lateral extent of the flood plain from the elevation of the standard project tide, i.e., the tide produced by a "hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region" (U.S. Army Coastal Engineering Center, 1966, p. A-17).

The standard project tide for the north shore of Nassau County varies from 18 ft above mean sea level (msl) at the western County boundary to 17 ft above msl at the eastern boundary (U.S. Army Corps of Engineers, 1972a). Because it is 17 ft above msl at Stamford, Conn. (U.S. Army Corps of Engineers, 1972a) the standard project tide is also 17 ft above msl at Eaton's Neck (U.S. Army Corps of Engineers, 1969, p. C5). The standard project tide is 13 ft above msl for Brookhaven township in Suffolk County (U.S. Army Corps of Engineers, 1972b). The design hurricane tide, which is very similar to the standard project tide, is 14 ft at Orient Point (U.S. Army Corps of Engineers, 1969, p. C5 and Fig. C-20). The standard project tide is not currently available for Orient Point.

Interpolation of the elevation contours on the most recent 7 1/2 minute quadrangle maps was then used to represent the standard project tide. Seventeen feet was used from Eaton's Neck westward. Fifteen feet was used for the region between Eaton's Neck and the entrance to Stony Brook Harbor, and the 13-ft elevation was used from Stony Brook Harbor eastward.

Structures

The number of habitation structures in the flood plain was determined from aerial photographs, field surveys and topographic maps. The number of man-made protective structures (groins, etc.) was determined from Table F1, U.S. Army Corps of Engineers (1969).

Bluffs and Dunes

The existence of bluffs and dunes as well as bluff height was determined from field studies, topographic maps, aerial photographs and the station profiles (Plates 29 to 40 in U.S. Army Corps of Engineers, 1969).

Our bluff recession data was determined by comparing 1933 series (approximate scale of 1:7200) and 1970 series (approximate scale of 1:4800) aerial photographs of the Nassau-Suffolk Regional Planning Board. Because erosion of 50 ft is represented by only 1/8 inch on the 1970 aerial photographs, a slight tilt or distortion in an aerial photograph would invalidate any measurement.

Bluff recession could be determined for a stretch of coast only if, first - in order to determine scale - there were adequate reference points on a 1933 aerial photograph and its corresponding 1970 aerial photograph and topographic quadrangle map and, second, there was no apparent scale variation within both the 1933 and 1970 aerial photographs. Five steps were then taken to determine bluff recession:

1. A straight line, approximately parallel to the coast, was drawn between two points on the 1970 aerial photograph.
2. A straight line was drawn between the same two points on the 1933 aerial photograph.
3. Equivalent perpendiculars to the lines were constructed on the 1933 and 1970 aerial photographs.
4. The lengths of the perpendiculars were determined.
5. The true difference in length was then the amount of bluff recession.

Grain Size Analysis

Grain size analysis followed the methods described by Galehouse (1971).

Beach Access

Beach access was determined on location at each field station.

Beach Profiles

Beach profiles were determined by the method of Emery (1961).

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The time it takes a man to realize the ability of littoral forces to alter segments of the coast, both in moving large volumes of material and in destroying costly human development, varies from a few hours (from severe storms) to many years (from normal weathering). Regardless of the time involved, the outcome is usually the same: shoreline damage and public outcry for protection against such damage in the future.

Man's interference with the shoreline in terms of channel dredging, harbor construction, landfilling, construction of jetties, groins and seawalls has caused the configuration of the shoreline to change. This change - the establishment of new conditions of shoreline equilibrium - is the response of winds, waves and tides interacting with the sediments and form of the shore. In all cases, this change has not been to the benefit of man. Often shore protection structures are built without enough knowledge of the littoral processes affecting the shore adjacent to the structure. Unwanted erosion or accretion may well result.

The practice of using jetties, groins, seawalls and beach fill for the protection of our shores must be critically evaluated. Such methods are extremely expensive and inherently dependent on the dynamics of the littoral zone, and hence may or may not perform their intended function. Future development of the north shore of Long Island should be designed to lessen the need for such massive structures, by means of rational land-use planning to limit potential storm damage from severe storms. Such planning requires understanding of both the processes affecting the configuration of the shoreline and the objectively determined needs for shore protection.

Rational shoreline management requires the use of scientific information in a number of contexts. This report attempts to assemble and synthesize the types of information useful to planners and engineers concerned with man's use of the shore zone. Available knowledge of shoreline processes is sufficient to outline rational shoreline management guidelines for Long Island's north shore.

Our conclusions are:

1. Long Island's surficial sediments and topography resulted from glacial deposition which ended roughly 15,000 years ago.
2. The present shoreline is the result of erosion and deposition since post-glacial sea level stabilization approximately 6,000 years ago. The bluffs of Long Island's north shore are unconsolidated, easily erodible sediments.
3. Long-term erosional trends are basically due to severe storms and sea-level rise.
4. Short-term erosion and accretion are due to severe storms, normal weather conditions, and man-made modifications.
5. The occurrence of a tropical cyclone in the Long Island area is a rare event. Tropical cyclones are most likely to occur over the central section of Long Island's north shore, where there is an 11 percent chance of occurrence in a given year.

6. Extratropical storms (northeasters) are frequent in the Long Island area. A northeaster causing significant water damage on Long Island occurs, on average, in eight of every ten years.

7. Bluffed coasts and bar beaches differ in their response to severe storm attack. Direct wave action is a primary cause of severe bluff erosion. Bar beaches are subject to dune destruction and extensive flooding.

8. Rain runoff is also a significant cause of bluff erosion. Locally, bluff erosion is intensified by extensive walking and climbing on the bluff face slopes.

9. Plots of erosion and accretion rates versus shoreline distance can be used to indicate areas which are suppliers of sediment and those areas where sediment is accumulating.

10. The beaches of the north shore are supplied with sediment from two major sources:

    (1) the bluffs, and (2) the glacial deposits beneath the beaches and nearshore bars. A large proportion of the glacial and bluff deposits consists of silts and clays which are removed from the shoreline and deposited in the deeper areas of Long Island Sound, thus lowering the amount of material available for beaches.

11. Widespread bluff stabilization and the maintenance of broad protective beaches are incompatible. Extensive attempts to stabilize eroding bluffs will, in the long run, adversely affect beach width by decreasing the supply of sediment nourishing the beaches. Decreases in beach width permit more intensive wave attack on the bluff face, further frustrating attempts to stabilize bluff slopes behind them. Loss of sediment supply from bluffs could cause the beaches to completely disappear in decades. This emphasizes the importance of the sand budget concept in beach management practice.

12. Neither individuals nor small community groups have the economic resources to achieve stable conditions in areas subject to erosion. Further, structures built for such purposes often cause erosion of beaches beyond the owners' properties.

<u>Recommendations</u>

1. Local ordinances should be modified by the establishment of a bluff hazard zone applicable to those areas of the north shore backed by eroding bluffs. The construction of dwellings on the top of the bluff should be prohibited within 100 feet from the edge of the bluff face, defined by an abrupt increase in slope.

2. Development on those lands contained in the flood plain of a 100-year storm should be controlled by use of flood plain zoning. Structures should not be built in the flood plain zone, with the exception of relatively inexpensive structures required for recreation. All future necessary construction on a flood plain should be located a sufficient distance from the shore, so as to minimize damage from short-term shoreline changes. Adequate construction set-back lines should be established.

3. Marinas and boat-launching areas should not be built on the open coast where they are subject to direct wave action, but in protected areas such as harbors.

4. Selection of sites for acquisition or development of bathing beaches should employ the utility index (Chapter 3) in addition to other factors such as the distribution of population density. This index should also be used as a guide for private development.

5. Engineering structures, such as groins, should not be constructed by governmental or private interests without sufficient knowledge of the processes affecting the area to insure that such structures will not increase erosion rates of adjacent property.

6. Natural shoreline vegetation should not be destroyed in the process of development. This includes not only beach vegetation, but also trees and shrubs on the face and tops of shore bluffs.

7. Recognizing the fact that wetlands protect adjacent uplands by absorbing wave energy, stabilizing banks and serving as storage areas for tidal waters, efforts should continue to protect wetlands from the adverse effects of shoreline development. Use of artificially created wetlands on a practical scale as inexpensive, self-maintaining buffers against erosion of appropriate stretches of Long Island's shoreline should be initiated.

8. Man's intentions to modify the shore zone should be reviewed and, if appropriate, carried out within the context of modern planning methods.

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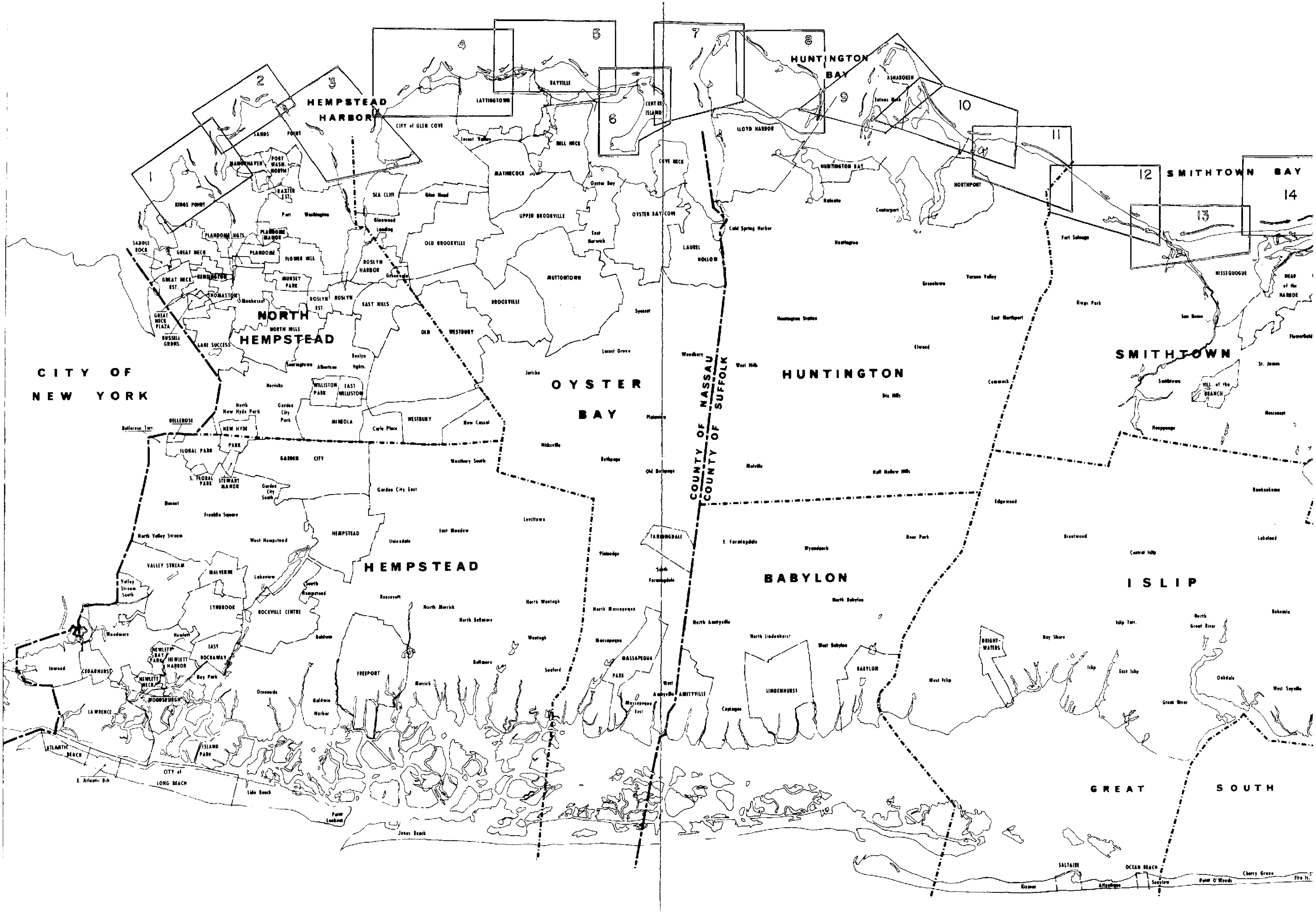
CITY OF NEW YORK
NORTH HEMPSTEAD
HEMPSTEAD HARBOR
HEMPSTEAD
OYSTER BAY
COUNTY OF NASSAU
COUNTY OF SUFFOLK
HUNTINGTON BAY
HUNTINGTON
BABYLON
SMITHTOWN BAY
SMITHTOWN
ISLIP
GREAT SOUTH
1
2
3
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5
6
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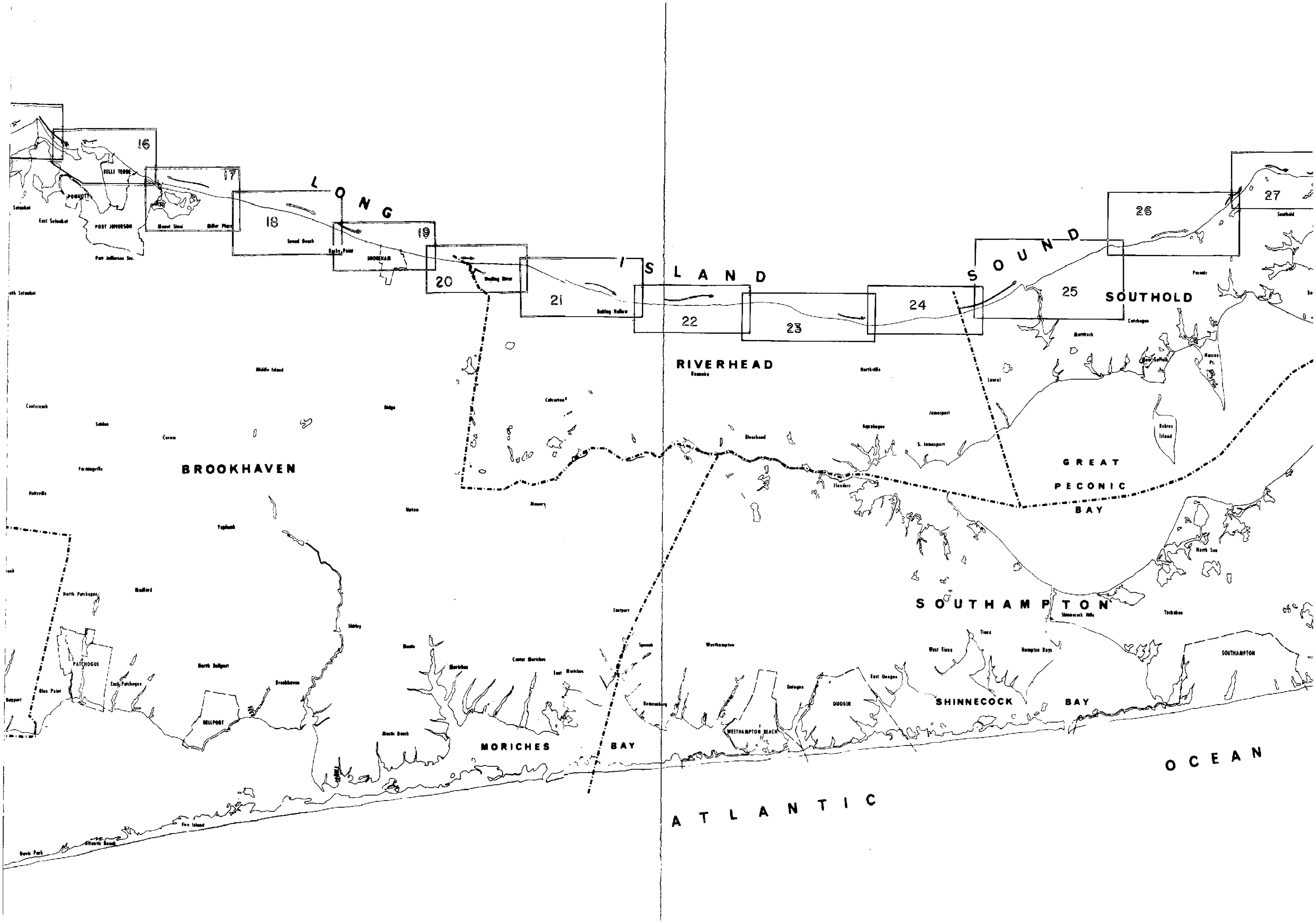
11
12
13
14
KINGS POINT
SANDS POINT
PORT WASH. NORTH
MANORHAVEN
BAXTER EST.
Port Washington
SADDLE ROCK
GREAT NECK
GREAT NECK EST.
KENSINGTON
THOMASTON
GREAT NECK PLAZA
RUSSELL GRDNS.
LAKE SUCCESS
PLANDOME HGTS.
PLANDOME MANOR
PLANDOME
FLOWER HILL
MUNSEY PARK
Manhasset
NORTH HILLS
ROSLYN EST.
ROSLYN
ROSLYN HARBOR
Greenvale
EAST HILLS
SEA CLIFF
Glen Head
Glenwood Landing
CITY of GLEN COVE
LATTINGTOWN
Locust Valley
BAYVILLE
MILL NECK
MATINECOCK
CENTRE ISLAND
COVE NECK
Oyster Bay
UPPER BROOKVILLE
OLD BROOKVILLE
East Norwich
OYSTER BAY COVE
LAUREL HOLLOW
BROOKVILLE
MUTTONTOWN
OLD WESTBURY
Syosset
Locust Grove
Jericho
Woodbury
WILLISTON PARK
EAST WILLISTON
Albertson
Roslyn Hgts.
Searingtown
Herricks
North New Hyde Park
NEW HYDE PARK
Garden City Park
MINEOLA
Carle Place
WESTBURY
New Cassel
BELLEROSE
Bellerose Terr.
FLORAL PARK
S. FLORAL PARK
STEWART MANOR
GARDEN CITY
Garden City South
Garden City East
Westbury South
Elmont
Franklin Square
North Valley Stream
West Hempstead
HEMPSTEAD
Uniondale
East Meadow
Levittown
Hicksville
Plainview
Bethpage
Old Bethpage
VALLEY STREAM
MALVERNE
Lakeview
Valley Stream South
LYNBROOK
ROCKVILLE CENTRE
South Hempstead
Roosevelt
North Merrick
North Bellmore
North Wantagh
Plainedge
FARMINGDALE
South Farmingdale
North Massapequa
Massapequa
MASSAPEQUA PARK
Woodmere
Hewlett
EAST ROCKAWAY
HEWLETT BAY PARK
HEWLETT HARBOR
HEWLETT NECK
WOODSBURGH
Inwood
CEDARHURST
LAWRENCE
Bay Park
Oceanside
Baldwin
Baldwin Harbor
FREEPORT
Merrick
Bellmore
Wantagh
Seaford
Massapequa East
West Amityville
AMITYVILLE
ATLANTIC BEACH
E. Atlantic Bch.
CITY of LONG BEACH
ISLAND PARK
Lido Beach
Point Lookout
Jones Beach
LLOYD HARBOR
HUNTINGTON BAY
Cold Spring Harbor
Halesite
Huntington
Centerport
ASHAROKEN
Eatons Neck
NORTHPORT
Greenlawn
Vernon Valley
Huntington Station
East Northport
West Hills
Elwood
Dix Hills
Commack
Melville
Half Hollow Hills
Fort Salonga
Kings Park
NISSEQUOGUE
HEAD of the HARBOR
San Remo
Smithtown
VILL. of the BRANCH
St. James
Hauppauge
Nesconset
Flowerfield
E. Farmingdale
Wyandanch
Deer Park
North Babylon
North Amityville
North Lindenhurst
West Babylon
LINDENHURST
Copiague
BABYLON
Edgewood
Brentwood
Central Islip
Ronkonkoma
Lakeland
BRIGHTWATERS
Bay Shore
Islip Terr.
North Great River
Bohemia
West Islip
Islip
East Islip
Great River
Oakdale
West Sayville
Kismet
SALTAIRE
Atlantique
OCEAN BEACH
Seaview
Point O'Woods
Cherry Grove
Fire Is.


LONG ISLAND SOUND
16
17
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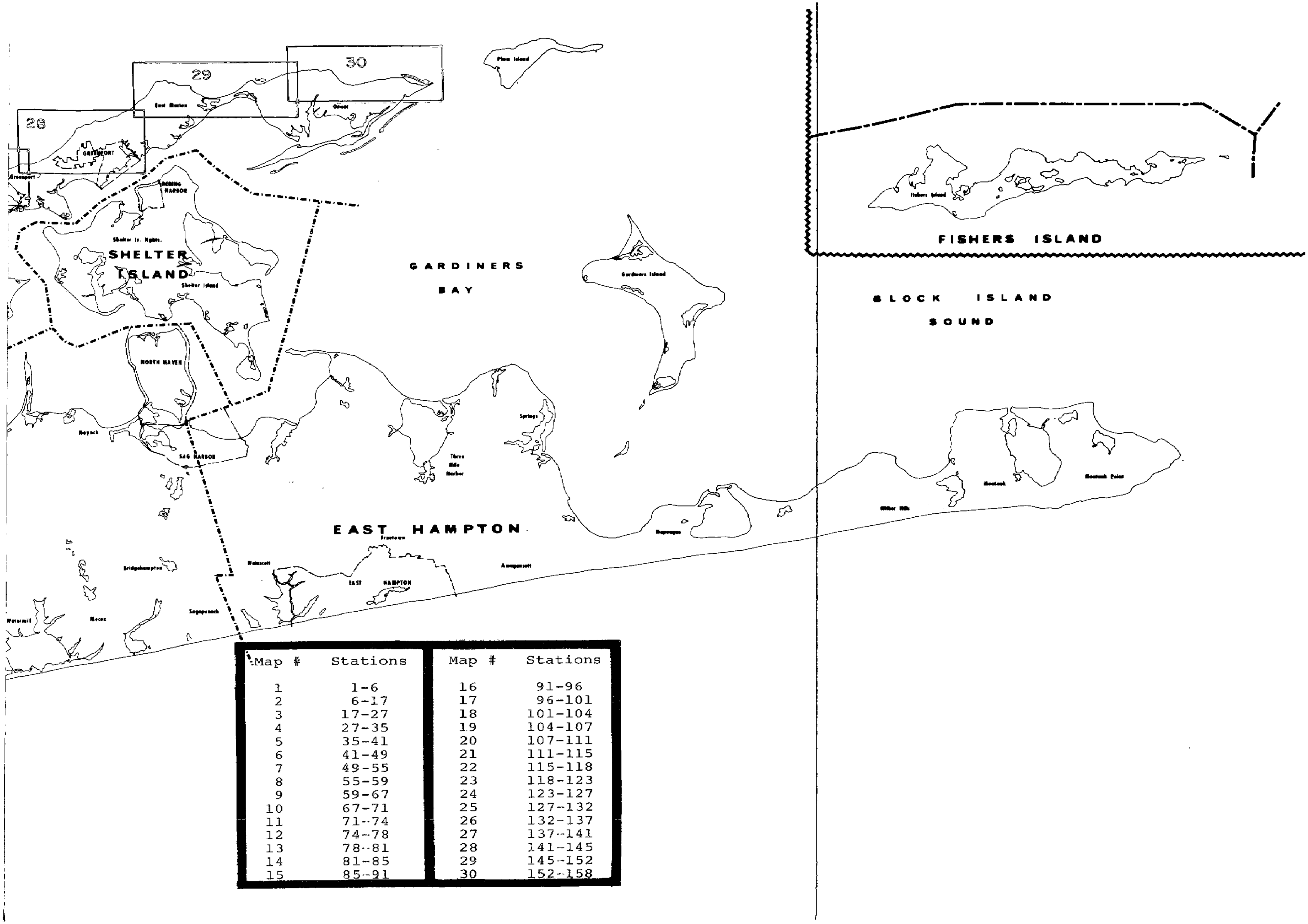
27
BROOKHAVEN
RIVERHEAD
SOUTHOLD
SOUTHAMPTON
GREAT PECONIC BAY
MORICHES BAY
SHINNECOCK BAY
ATLANTIC OCEAN
PATCHOGUE
BELLPORT
PORT JEFFERSON
SHOREHAM
WESTHAMPTON BEACH
QUOGUE
SOUTHAMPTON



Map #	Stations	Map #	Stations
1	1-6	16	91-96
2	6-17	17	96-101
3	17-27	18	101-104
4	27-35	19	104-107
5	35-41	20	107-111
6	41-49	21	111-115
7	49-55	22	115-118
8	55-59	23	118-123
9	59-67	24	123-127
10	67-71	25	127-132
11	71-74	26	132-137
12	74-78	27	137-141
13	78-81	28	141-145
14	81-85	29	145-152
15	85-91	30	152-158